WINTER SIMULATION CONFERENCE

WSC'18

GOTHENBURG ★ SWEDEN

SIMULATION FOR A NOBLE CAUSE

Program & Exhibit Directory

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2018 Winter Simulation Conference

Simulation for a Noble Cause

Final Program
Exhibit Directory

December 9-12, 2018
The Swedish Exhibition & Congress Centre
Gothenburg, Sweden

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PhD Colloquium & General Poster Session, 5:30pm-7:00pm* Sunday and 5:30pm-6:30pm, Monday, Congress Foyer
*Posters will remain in the Congress Foyer through Wednesday

Vendor Workshops - Sunday
Free, in-depth workshops from leading simulation vendors. See page 5 for details.

Vendor Tutorial Sessions – Monday & Tuesday
Exhibiting companies will present software tutorials, case studies, customer testimonials and introductory training sessions in these tracks, part of the regular technical program.

World Café – Monday thru Wednesday
First time at WSC. Participants will discuss topics of high interest at different tables over lunch. Ideas, questions, and concerns will be captured on first two days and reported out in a session on Wednesday.

Program & Events Schedule

See Quick Reference Guide (separate handout) for room locations.

Sunday, December 9

8:00am-6:00pm	Registration	Congress Foyer Reception
8:30am-12:00pm	Data Farming 101 Workshop	R2
10:00am-12:00pm	*Vendor Workshops*	
	Flexsim	R17
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PhD Colloquium		
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7:00pm-8:30pm	Welcome Reception *Hosted by City of Gothenburg*	Congress Foyer
8:30pm-9:00pm	New Attendee Orientation	J2

Monday, December 10

7:00am-5:00pm	Registration	Congress Foyer Reception
8:00am-9:30am	Welcome & Keynote	Congress Hall
9:30am-5:30pm	Exhibits Open	Hall H
9:30am-10:00am	Refreshment Break	Hall H
10:00am-11:30am	Military Keynote: Huber	R17
10:00am-11:30am	Technical Sessions	See program
11:30am-12:15pm	Light Lunch Provided	Hall H
	World Café - I†	Congress Foyer
12:20pm-1:20pm	Titan of Simulation: Peter Frazier	Congress Hall
1:30pm-3:00pm	Technical Sessions	See program
3:00pm-3:30pm	Refreshment Break	Hall H
3:30pm-5:00pm	Technical Sessions	See program
5:30pm-6:30pm	Poster Session (continued)	Congress Foyer
5:30pm-8:30pm	Journal of Simulation Meeting	R31
6:30pm-8:30pm	General Reception	F Area

Tuesday, December 11

7:00am-5:00pm	Registration	Congress Foyer Reception
8:00am-9:30am	Technical Sessions	See program
9:30am-5:30pm	Exhibits Open	Hall H
9:30am-10:00am	Refreshment Break	Hall H
10:00am-11:30am	Technical Sessions	See program
11:30am-12:15pm	Light Lunch Provided	Hall H
	World Café - II†	Congress Foyer
12:20pm-1:20pm	Titan of Simulation: Russell Cheng	Congress Hall
1:30pm-3:00pm	Technical Sessions	See program
3:00pm-3:30pm	Refreshment Break	Hall H
3:30pm-5:00pm	Technical Sessions	See program
3:30pm-5:00pm	MASM Keynote: Mönch	R14
5:30pm-6:30pm	ACM/SIGSIM Meeting	R11
6:15pm-8:00pm	INFORMS-SIM Meeting	R2
6:30pm-8:30pm	Vendor User Groups	See page 5
6:30pm-8:00pm	MASM Reception	R14

Wednesday, December 12

7:00am-11:30am	Registration	Congress Foyer Reception
8:00am-9:30am	Technical Sessions	See program
9:00am-11:30am	Exhibits Open	Hall H
9:30am-10:00am	Refreshment Break	Hall H
10:00am-11:30am	Technical Sessions	See program
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† Lunch tables with designated discussion topics for interested attendees
*Pre-registration was required.

Special Events

City of Gothenburg

Welcome Reception hosted by City of Gothenburg

Join us on Sunday, December 9 from 7:00-8:30pm for light snacks and drinks in the Congress Foyer at Gothia Towers/Svenska Mässan. City Council representatives will welcome WSC guests to Gothenburg, a Sustainable City Open to the World!

New Attendee Orientation

If you are attending WSC for the first time, don't miss this informal and informative orientation on Sunday, December 9 from 8:30-9:00pm, in J2. Typically, over 30% of WSC attendees identify themselves as first-timers. The WSC '18 Committee will be on hand to answer your questions.

Exhibits

Take this opportunity to meet with vendors of simulation software, applications and services, and with representatives of simulation-related professional societies. Displays and demonstrations allow you to examine and compare many different products and services. You also have the chance to talk informally with the developers of leading simulation products. Exhibits are open:

Monday	9:30am-5:30pm
Tuesday	9:30am-5:30pm
Wednesday	9:00am-11:30am

Exhibitor directory and floor plan on pages **148-155**.

Speaker Ready Room and Speaker Lounge

Speakers and session chairs that are guests of Gothia Towers are encouraged to enjoy the breakfast buffet that is served in the hotel restaurant. We have a speaker ready room available in R9 and a Speaker Lounge in the R11/R12 Foyer. This space is open for you to use to schedule meeting times or just to sit and relax and catch up with fellow speakers and session chairs.

Monday Evening Reception

Join us on Monday evening, 6:30-8:30pm in the F Area on Level 2 for good food and camaraderie. The reception is a great place to meet with other simulation professionals, many of your old friends, and just relax and recharge for the rest of the week. The menu at this reception will be finger foods, inspired by Swedish Christmas. Admission to the party is included in your registration fee; guest tickets are available at the WSC registration desk ($20).

User Group Meetings

Plan to attend these informative meetings on Tuesday evening, 6:30pm-8:30pm.

Group	***Room***
The AnyLogic Company	R31
Applied Materials	R4
Simio Simulation & Scheduling Software	J2
Amazon	R15

Sponsors

The Winter Simulation Conference 2018 expresses thanks to the organizations who have contributed direct financial support to help make this conference a success.

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Sponsoring Societies

- ACM/SIGSIM: Association for Computing Machinery: Special Interest Group on Simulation
- ASA: American Statistical Association, Technical Co-Sponsor
- ASIM: Arbeitsgemeinschaft Simulation, Technical Co-Sponsor
- IEEE/SMC: Institute of Electrical and Electronics Engineers: Systems, Man, and Cybernetics Society, Technical Co-Sponsor
- IISE: Institute of Industrial and Systems Engineers
- INFORMS-SIM: Institute for Operations Research and the Management Sciences: Simulation Society
- NIST: National Institute of Standards and Technology (NIST), Technical Co-Sponsor
- ORS: The Operational Research Society (UK), Technical Co-Sponsor.
- SCS: The Society for Modeling and Simulation International

Preface

From the General Chair

Welcome to the 2018 Winter Simulation Conference (WSC), an annual gathering of researchers and practitioners from around the world, and across industry, academia and governments.

This year, the theme is "Simulation for a Noble Cause" which reminds us all about the power contained within knowledge and awareness achieved from modeling and simulation. It is up to each individual to take responsibility for the actions we perform in order to impact our society for a noble cause, i.e. aiming at circularity and preserving the globe while at the same time make efforts towards a more socially balanced society.

In addition to our traditional lineup of tracks, our Program Chair, **Sanjay Jain**, has organized special program content both on "Simulation for a Noble Cause" as well as putting extra effort on a couple of tracks such as Homeland Security Enterprise and Simulation Standards and Reproducibility.

We have a great line-up of featured speakers this year. We begin with a conference keynote address from **Scott Breor**, who is serving as the Deputy Assistant Secretary (Acting) for the Office of Infrastructure Protection within the U.S. Department of Homeland Security. The context of infrastructure and resilience on how to maintain water, energy and other resources for the society in various unexpected events are addressed using modeling and simulation for a noble cause. This year, two of our tracks will feature keynotes as well. The Military keynote is **Reiner Huber**, who presents a recollection and perspective on Military Modeling and Simulation. Our MASM keynote speaker is **Lars Mönch**, speaking on Reference Modeling, Simulation Testbeds, and Reproducibility. Finally, we are pleased to offer two lunchtime presentations in our Titans of Simulation series. **Peter Frazier** presents how to Bridge the Gap from Academic Research to Industry Impact, and **Russell Cheng** describes how to Create a Real Impression using Visual Statistical Analysis. This year's PhD Colloquium Keynote is **Stewart Robinson**, who will elaborate on the question: Are you Building and Using the Best Model? How did the WSC end up in a small town like Gothenburg with merely half a million inhabitants? Persistently making the case and consistently serving the conference since early 2000 has finally resulted in the second WSC outside of the US. And pointing out that Gothenburg average December temperature is higher than that we suffered in Baltimore throughout the 2010 conference helped too…

A large part of this longevity of WSC is attributable to the remarkable consistency and quality of the program and conference experience from year to year. As most of you know, this quality and consistency does not happen by accident. Conference planning and preparation is a 5-year process guided by the WSC Board of Directors, whose members represent our sponsoring societies. Members of the board typically serve 6-10 year terms, and have often served in conference organization roles prior to their service on the board. They provide the essential institutional memory that enables the continuity of the conference year after year. I am grateful to all of them for their support along the road to WSC 2018. Especially all persons of the board who helped with the heavy burden of scouting out locations for the conference and pursuing the idea to host WSC in Gothenburg, Sweden. All wisdom, advice and guidance from previous WSC organizers has been an essential asset to make WSC 2018 successful.

Each conference is a result of the efforts of the conference committee along with the board's guidance. WSC 2018 has been fortunate to have a tremendous team of volunteers. I am honored to have been working with each of them. In particular, I would like to acknowledge: Our Program Chair, **Sanjay Jain**, put in many long hours and organized a fantastic program. Our Business Chair, **Oliver Rose**, kept us strict and sound for a conference experience worthwhile to remember: both for the scientific content as well as for the venue, the food, the food and some more food! Our Proceedings Editors, **Markus Rabe**, **Angel Juan**, **Navonil Mustafee**, and **Anders Skoogh**, worked with our authors and publisher to produce a high-quality record of this landmark conference. Our Board Liaison, **Lin Uhrmacher**, for quick response and guidance on critical decisions. Exhibit Chairs, **Camilla Lundgren** and **Joe Hugan** organized a high quality and extensive collection of booths in the exhibit hall. Please visit the booths often! Our Sponsorship Chairs, **Renee Thiesing** and **Karthik Vasudevan**, coordinated academic and corporate sponsorships with items and attendee giveaways, study visits and photo opportunities. Our Registration Chair, **Jonatan Berglund**, ensured that

all our authors were successfully registered and handled the processing of visa and invitation letters, as needed, for our international attendees. Our Publicity Chairs, **Simon Taylor**, **Jesus Jiminez**, **Loo Hay Lee** and **Alejandro Berbetty**, did a fantastic job of publicizing the conference through surface and electronic mail, as well as through our social media presence on LinkedIn, Facebook and Twitter. Finally, **Mike Kuhl** for his continuous work on the WSC mobile app.
In addition to our hard working volunteers, WSC enlists the professional services of Omnipress, our publisher, Linklings, our web-based paper management partners, and INFORMS, for our web site and conference management services. The continuous positive assistance (during the last eight years!) from the personnel at Gothia Towers **Suzanne Murén** and the city of Gothenburg **Anna Hylander,** was a key enabler for this successful event. A very special thanks to **Liz Hood** for her essential support to the conference. We could not have done this without her!

On a personal note, I would like to express my gratitude to the many talented and caring persons in our WSC-community. I got a very warm welcome at my first WSC year 2001. The WSC has been and is a landmark every year for our field, filled with inspiring talks, discussions, laughter and caring advice for each other. Many continuous attendees know my family: my wife and three kids, which makes it even more family-like. I have grown up in this WSC-community and consider it family. I have learned a lot from persons like **Russell Barton, Enver Yücesan, Ann Dunkin, Manuel Rosetti, John Sokolowski, Ernest H. Page, Andreas Tolk, Christos Alexopoulos, Jeff Joines, Jeffrey Smith, Guodong Shao, Charles McLean**, **Jerry Banks** and many more in this community. My goal is to multiply that favor, to contribute with the same advice and knowledge sharing for the future. It is and was a privilege to work with each of you in bringing about this amazing journey resulting in the Winter Simulation Conference 2018 in Gothenburg, Sweden.

Finally, thanks to all our authors, referees, track chairs, session chairs, and attendees. For many of you WSC is an anticipated annual reunion with colleagues and friends. And for some of you, this could be your first WSC. I hope you are pleased with the experience and can feel the warm welcoming atmosphere. Enjoy and share your knowledge on modeling and simulation for a better future! Welcome and ***Avances!***

Björn Johansson
WSC 2018 General Chair

From the Program Chair

It is time we focused on employing simulation for noble causes!

Simulation has been found useful for a range of scientific, engineering and business applications as evident by the papers presented at Winter Simulation Conferences over the past 50 years. Simulation has been employed to help noble causes too over the recent past but such efforts have received limited attention. In the 2018 conference we seek to highlight applications of simulation for noble causes in addition to continuing to report leading developments and applications in other fields. I especially encourage the attendees to attend sessions with papers describing uses of simulation in efforts analyzing and addressing issues facing humanity including, but not limited to, reducing human trafficking, addressing social causes, improving natural environment, and disaster response.

It has been an honor to coordinate the scientific program for this year. The results of the efforts of all the participants can be witnessed in the high quality of the Proceedings. The Program for WSC 2018 includes three categories of articles: contributed full papers, invited full papers and extended abstracts. The papers in the first two categories were rigorously reviewed and they will be archived in both the IEEE and ACM Digital Libraries. This year, 261 contributed full papers were submitted for review, of which 184 (or 70%) are published. In addition, 173 invited full papers were submitted for review, of which 161 (or 93%) are published, bringing the total number of full paper submissions to 434. The 345 selected, peer-reviewed papers constitute the core of the WSC 2018 Program. The third category of submissions consists primarily of extended abstracts for the Poster, Industrial Case Studies, and Vendor tracks, as well as the PhD colloquium. These submissions are not published within IEEE and ACM; however, they are available within the program and the WSC Web Archive. This year, the number of submissions in this category was 117. Of these, 98 (or 84%) will be presented at the conference. In summary, WSC 2018 had 551 submissions, out of which 443 made it into the Program. The accepted submissions were authored by 1126 different researchers from 41 countries in six continents.

Within the program, the submissions have been organized into 18 parallel streams at the conference. Our keynote speaker will open the discussion about the use of simulation for noble causes, the theme for 2018. There are two tutorial tracks: Introductory and Advanced. The key modeling and methods tracks include agent-based simulation, modeling methodology, complex, intelligent, adaptive and autonomous systems, cyber-physical systems, hybrid simulation, and simulation, standards and reproducibility. The key analysis tracks include simulation optimization and analysis methodology. The key application oriented tracks include aviation modeling and analysis, environmental and sustainability applications, gaming, healthcare applications, homeland security enterprise, logistics, supply chain modeling and transportation, manufacturing applications, military applications, networks and communications, project management and construction, simulation education, and of course, simulation for a noble cause. The WSC continues its long relationship with MASM, Modeling and Analysis of Semiconductor Manufacturing, the conference within the conference. There are special panels on ethics of modeling and simulation, reproducibility, education on model simplification, challenges and opportunities in hybrid simulation, and on Dynamic Data Driven Applications Systems.

Two tracks included on Sunday are the PhD colloquium and the Poster Flash Presentations. Posters from these two tracks will be on display Sunday early evening after presenters provide overviews during the afternoon. They provide forums for researchers and students to discuss their work, and the posters will remain available during the conference. Practitioners will exchange ideas within Case Studies Track. Vendors will present their latest tools and techniques in the vendor tutorial track during the main conference, as well as in workshops on Sunday.

The high quality of the WSC program could not be accomplished without the hard work of the program committee, track coordinators, and reviewers. We conducted 1439 reviews of high quality, from 55 Track Chairs, their 445 Track Program Committee Members and another 117 External Reviewers. You will find a list of all the track coordinators towards the end of the program booklet. My sincerest thanks for all of their hard work. I would like to recognize the proceedings team, **Markus Rabe, Angel Juan, Navonil Mustafee** and **Anders Skoogh** for their dedicated service to the quality of the WSC proceedings. It was a pleasure to collaborate with Markus, who led the team that was responsive and effective, and worked tirelessly to ensure the high quality of the papers in the conference. Likewise, the extreme dedication of track chairs in ensuring the quality of the materials and the prompt response to all the questions to the authors is invaluable. Notably, **Markus Rabe** and **Dave Goldsman**, in charge of the Logistics, SCM and Transportation track, were always ready in advance and provided good ideas for the overall effort. In addition, without the support of **Mark Montague, Luke Montague,** and **Leah Glick** at Linklings, it would have been impossible to complete the many tasks necessary within the Paper Management System. I would like to recognize the tireless work of **Liz Hood** of **INFORMS** for the administrative support for the conference. I would also like to thank **Lin Uhrmacher,** our WSC board liaison and the **WSC board,** led by **Enver Yücesan,** for their guidance and support.

Finally, I would like to thank our General Chair, **Björn Johansson,** and our Business Chair**, Oliver Rose,** for the integrated teamwork that allowed the three of us to spearhead the effort of pulling this event together. Björn and I discussed running the conference together when we worked jointly on the editing team of WSC2010, and I am happy that we were able to bring the idea to reality. My first Wintersim was in the first year of my professional career in 1989. I already had the conference in high regard having referred to conference proceedings extensively during my doctoral research years. While in early 90s I was not able to join every year with the pressures of an industry career, I have enjoyed the conference every year continuously for the last 20 years.

It has been an honor to have this opportunity to serve the conference.

Sanjay Jain
WSC 2018 Program Chair

From the Editors

Many people have contributed to making this Winter Simulation Conference a success. Our thanks go first and foremost to all the authors for not only choosing WSC for disseminating their research, but also for their patience and help in getting the papers to a really nice and unified format. Without their diligence and responsiveness, we could not have produced these proceedings in such high quality. The efforts of the track chairs, track program committees, and referees were instrumental in shaping the program by defining a substantial and innovative program as well as facilitating a strict peer-review process.

The program includes around 350 full papers distributed over 23 tracks as well as many abstracts, including contributions from vendors, industrial cases, and poster presentations. All accepted full papers will be submitted and published in both the ACM and IEEE Digital Libraries, which are usually indexed in the Scopus and Web of Science databases. The remaining materials will also be available through the WSC web archive. The poster session will give presenters an opportunity to share their work-in-progress and receive valuable feedback from the conference attendees. Such interactions are expected to lead to potential avenues for future collaborations. Those Ph.D. students who have submitted a full paper in addition to taking part in the Doctoral Colloquium compete for the best paper awards, which will be presented by ACM/SIGSIM and INFORMS Simulation Society.

For 2018, the proceedings editors have unified and more precisely described the rules for writing and formatting WSC papers, leading to a further improved formal quality and appearance in print. Further opportunities for improvement have been identified while working on the proceedings for this year, and these will be carried forward to the template for WSC 2019. We would like to particularly thank the authors who have identified some of these opportunities. Together with the strict revision of the papers by three independent reviewers and the responsible track chairs, all these measures lead to WSC being recognized as high-quality and highly renowned publication outlet.

We also would like to acknowledge the always outstanding support provided by the *Linklings* team in helping us to improve our ability to manage the papers and streamline the editorial process.

As the WSC 2018 editorial team, we hope everyone enjoys this year's program and takes advantage from reading the papers and discussing their research in Gothenburg.

Markus Rabe
Angel A. Juan
Navonil Mustafee
Anders Skoogh
WSC 2018 Proceedings Editors

In Memoriam: Julian Reitman (1925-2018)

Over the course of seven decades, Julian Reitman made groundbreaking contributions to the field of computer simulation and the Winter Simulation Conference (WSC). This commemoration of Julian highlights various facets of his remarkable professional career, including his numerous technical contributions as well as his service to WSC and the international simulation community.

From the late 1940s through the 1950s, Julian worked on the design of electroacoustic test equipment and a real-time, dial-up airline reservation system that was capable of handling extended periods of peak loading while operating around the clock. These experiences convinced him of the urgent need for significantly more effective tools to simulate such complex systems on a digital computer.

In the early 1960s Julian led pioneering applications of the original General Purpose Simulation System (GPSS) in a broad diversity of disciplines ranging from the design of computer-based telecommunication systems to military effectiveness studies of carrier-based aircraft operations; and some of the resulting simulation models evolved and remained in use for almost three decades. In the late 1960s Julian led the development of the GPSS/360–Norden simulation language, which incorporated innovations that were decades ahead of their time, including (i) memory-management facilities for executing a large-scale simulation, possibly requiring access to a large database; and (ii) graphical, interactive facilities for debugging, animating, monitoring, and controlling the execution of a large-scale simulation model.

In 1965 Julian was one of the founders of the Systems Science and Cybernetics Group (now the Systems, Man, and Cybernetics Society or SMC) of the Institute of Electrical and Electronics Engineers (IEEE), serving later as a member of the administrative committee (1967) of IEEE/SMC and as its chair (1969). Subsequently he served the larger IEEE organization in several editorial and administrative positions; and in recognition of his long-standing service, he was named a Senior Life Member of IEEE.

Julian was one of the founders of WSC. He was its first program chair (1967) and its second general chair (1968). Moreover, he led the effort to secure sponsorship for the 1967 conference by the Association for Computing Machinery (ACM); IEEE/SMC; and the IEEE Computer Group (now the IEEE Computer Society). He set the record as longest-serving member of the WSC Board of Directors (1967–1985), a distinction that is unlikely ever to be surpassed.

Julian also made significant contributions to the simulation literature since the early 1960s.

- He wrote many archival journal articles and proceedings papers on system simulation that have enduring interest among practitioners and researchers. Since the ACM Digital Library began to monitor downloads of its archival material in May 2003, Julian's contributions to ACM publications have been downloaded 1,716 times—including 34 times during the period September 2017–August 2018.
- He edited a special issue of the IEEE Transactions on Systems Science and Cybernetics (Volume SSC-4, Number 4, November 1968) that documented some of the presentations given at the 1967 conference.
- He was recognized at the 2007 WSC in a session titled "Fortieth Anniversary Special Panel: Landmark Papers" for the following article: Reitman, J., D. Ingerman, J. Katzke, J. Shapiro, K. Simon, and B. Smith. 1970. "A Complete Inter- active Simulation Environment GPSS/360–Norden." In *Proceedings of the Fourth Conference on Applications of Simulation*, edited by P. J. Kiviat and M. Araten, 260–270. Because of their long-term impact on simulation practice, theory, and education, ten epoch-making articles were selected for this session from four decades of WSC *Proceedings* articles. In Reitman et al. (1970), Julian and his collaborators pioneered the use of animation and visually based data- management tools long before the availability of personal computers and software for animation and spreadsheets.
- As a natural outgrowth of his teaching courses on discrete system simulation in the graduate schools of New York University and the University of Bridgeport as well as in Norden plants around the country,

Julian was ultimately led to write one of the first simulation textbooks, Reitman, J. 1971. *Computer Simulation Applications: Discrete-Event Simulation for Synthesis and Analysis of Complex Systems*. New York: Wiley-Interscience.

- He served on the following editorial boards: the IEEE Press (1969–1974); the *IEEE Transactions on Systems Science and Cybernetics* (1970); the *IEEE Transactions on Systems, Man, and Cybernetics* (1971–1983); and the *ACM Transactions on Modeling and Computer Simulation* (1991–1995).

Beginning in the mid-1980s, Julian focused much of his effort on the history of science and technology, including the history of simulation and WSC as documented in the following:

Reitman, J. 1988. "Keynote Address: A Concise History of the Ups and Downs of Simulation." In *Pro ceedings of the 1988 Winter Simulation Conference*, edited by M. Abrams, P. Haigh, and J. Comfort, 1–6. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers.

Araten, M., H. G. Hixson, A. C. Hoggatt, P. J. Kiviat, M. F. Morris, A. Ockene, J. Reitman, J. M. Sussman, and J. R. Wilson (moderator). 1992. "Twenty-Fifth Anniversary Panel Discussion, The Winter Simula- tion Conference: Perspectives of the Founding Fathers." In *Proceedings of the 1992 Winter Simulation Conference*, edited by J. J. Swain, D. Goldsman, R. C. Crain, and J. R. Wilson, 37–62. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers.

Schriber. T. J., J. Reitman, A. Ockene, and H. G. Hixson. 2017. "History of the Winter Simulation Confer- ence: Origins and Early Years (1967–1974). In *Proceedings of the 2017 Winter Simulation Conference*, edited by W. K. V. Chan, A. D'Ambrogio, G. Zacharewicz, N. Mustafee, G. Wainer, and E. Page, 40–49. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers.

Julian also taught numerous undergraduate and graduate courses on the history of science and technology at the University of Connecticut, Stamford (1987–1995), George Mason University (1988–1990), and other institutions.

Julian Reitman's professional achievements are unparalleled not only for their impact on the simulation field and WSC but also for the duration of that impact. He will always be an inspiration and role model
for everyone in the international simulation

KEYNOTE ADDRESS

Monday, 8:00am-9:30am
Congress Hall

Assessing Critical Infrastructure Dependencies and Interdependencies

Scott F. Breor
Deputy Assistant Secretary (Acting)
Office of Infrastructure Protection, U.S. Department of Homeland Security

Today's infrastructure is connected to many other infrastructure assets, systems, and networks that it depends on for normal day-to-day operations. These connections, or dependencies, may be geographically limited or span great distances. The many points of infrastructure connections, and their geographic distribution, make the infrastructure environment much more complex. The U.S. Department of Homeland Security (DHS) works to strengthen critical infrastructure security and resilience by generating greater understanding and action across a (largely) voluntary partnership landscape. This is achieved by working with private and public infrastructure stakeholders to resolve infrastructure security and resilience knowledge gaps, inform infrastructure risk management decisions, identify resilience-building opportunities and strategies, and improve information sharing among stakeholders through a collaborative partnership approach. This paper highlights the Department's efforts to present a more comprehensive picture of security and resilience through a "system of systems" approach.

SCOTT BREOR currently serves as the Deputy Assistant Secretary (Acting) for the Office of Infrastructure Protection (IP) within the U.S. Department of Homeland Security's (DHS) National Protection and Programs Directorate (NPPD), where he helps oversee IP's efforts to help secure the nation's critical infrastructure. Previously, Mr. Breor served as the Director of IP's Protective Security Coordination Division (PSCD), where he oversaw a nationwide cadre of critical infrastructure security specialists known as Protective Security Advisors (PSAs). He also led the division's efforts in vulnerability and security gap analysis; support to special events; and training on topics including active shooter preparedness; suspicious activity reporting; and improvised explosive device (IED) awareness and bomb threat management. Mr. Breor has over thirty years of military and senior executive experience in the United States government. Prior to DHS, Mr. Breor was a Naval Aviator and had served as the Senior Policy Advisor for the Chief of Naval Operations on all Homeland Security matters. While assigned to the Office of the Chief of Naval Operations (CNO) he led a division that supported the CNO on key warfare and Homeland Security and Defense policy decisions, which included: interagency coordination, incident management, and Department of Homeland Security/Department of Defense integration. For his work for the CNO and his efforts following the tragic events of September 11, 2001 at the Pentagon, he was awarded the Legion of Merit. As a Naval Aviator he supported operations in Iceland, Greenland, Adriatic, Mediterranean, Azores, and South America. Mr. Breor was a Senior Executive Fellow at the John F. Kennedy School of Government, Harvard University. He received a Masters of Arts in National Security Studies and in Homeland Security and Defense from the Naval Post Graduate School, and received a Masters of Business Administration from the University of Oklahoma. In addition, he earned a Bachelor of Science in Physics from The Citadel.

TITANS OF SIMULATION

Monday, 12:20-1:20pm
Congress Hall

Bridging the Gap from Academic Research to Industry Impact

Peter I. Frazier
Associate Professor, Cornell University; Staff Data Scientist and Data Science Manager, Uber

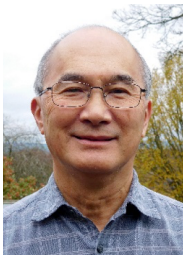
Academic methodological research is often done with the hope of creating mathematical methods that will be used in practice. At the same time, there is a significant gap between publishing papers and having the methods described actually be used in industry. In this talk, we offer advice for bridging this gap. We discuss challenges arising from a difference in focus between academic and industry research, and also an incomplete awareness within academia of the full context in which methods are deployed in industry. We then discuss strategies for overcoming these challenges, describing them using examples from the presenter's experiences as a data science manager at Uber working on Uber's carpooling product, UberPOOL, and as an academic developing Bayesian optimization algorithms for use at Yelp and the Bayesian optimization startup company SigOpt. This talk is aimed at academics who want their research to be used in industry, soon-to-graduate PhD students who are making a leap into an industry career, and practitioners interested in exploring ways to be more effective.

Peter I. Frazier is an Associate Professor in the School of Operations Research and Information Engineering at Cornell University, and a Staff Data Scientist at Uber. He received a Ph.D. in Operations Research and Financial Engineering from Princeton University in 2009. His academic research is in optimal learning, including Bayesian optimization and optimization via simulation, focusing on applications in e-commerce, materials design, and transportation. At Uber, he managed data science for UberPOOL, Uber's carpooling product, from 2015 to 2016 while on sabbatical leave from Cornell, and now advises a number of driver-focused data science teams. He is an associate editor for Operations Research, ACM TOMACS, and IISE Transactions, and is the recipient of an AFOSR Young Investigator Award and an NSF CAREER Award. His email address is pf98@cornell.edu.

TITANS OF SIMULATION

Tuesday, 12:20-1:20pm
Congress Hall

Creating a Real Impression: Visual Statistics Analysis



Russell Cheng
Emeritus Professor, University of Southampton

Many powerful statistical methods available for studying simulation output, are under-appreciated and consequently under-used because they are considered to be hard-to-understand, arcanely mathematical, and hard to implement. Such methods can invariably be implemented using data-driven resampling methods, making their underlying rationale quite transparent. There is little need for much formal mathematics, and what there is can be made visually obvious, with method and results explained and presented using figures and graphs, often with dynamic, animation. This approach in studying simulation output will be illustrated by a number of examples drawn from real applications and simulation studies. A bonus of the approach is that it is quite easy to create one's own 'bespoke' method of analysis tailored to a particular problem. Such an example will be presented and analyzed in 'real-time' in the talk itself, enabling the results to be immediately displayed.

Russell Cheng is Emeritus Professor at Southampton having been Professor of Operational Research and Head of the OR Group from 1999 to 2007, in the School of Mathematics. He obtained an MA from Cambridge University, and a PhD from the University of Bath. He was previously Deputy Director of the Institute of Mathematics and Statistics and Head of Management Science at the University of Kent at Canterbury. His research interests have been in: Design and Analysis of Simulation Experiments, Non-standard Parametric Estimation, Computer Generated Graphics, Optimal Control of Industrial Processes, and Marine Simulation. He is a former Fellow of the Royal Statistical Society, a Fellow of the Institute of Mathematics and Its Applications, and is a past Chairman of the United Kingdom Simulation Society. He is a past Board Member of EUROSIM, the Federation of Simulation Societies in Europe. He has been an Associate Editor of Management Science and was Joint Editor of the IMA Journal of Mathematics Applied in Business and Industry, and then founding Editor of the IMA Journal of Management Mathematics for which he received, in 2008, the IMA's Certificate of Service. He was Council member of the INFORMS Simulation Society (2006-08) and received the Society's Distinguished Service Award in 2007 and Lifetime Professional Achievement Award in 2016. He was the Consultant Research Director of Norcontrol Imaging Systems Ltd, a subsidiary of Norcontrol a.s., the largest manufacturer of marine simulators worldwide. He is author of the book Non-Standard Parametric Statistical Inference published in 2017 by Oxford University Press. He is currently a course lecturer in the UK's National Taught Course Centre in Operational Research (NATCOR) which delivers nationwide residential courses to UK research students in OR and Management Science.

MILITARY KEYNOTE

Monday, December 10, 10:00am-11:30am
R17

Military Modeling and Simulation—A Recollection and Perspective

Reiner Huber
Emeritus Professor, University of the German Armed Forces, Munich, Germany

The roots of today's military modeling and simulation approaches date back to 1938 when OR emerged after a disappointing exercise conducted by the RAF to test the effectiveness of the newly developed radar. It is fair to say that OR support in WWII was decisive in winning the Battle of Britain in 1940 and the Battle of the Atlantic in 1943. After WWII, military OR was re-awakened by NATO when the Cold War began by facilitating the build-up of national military OR institutions to support defense planners and militaries in sustaining a NATO force structure capable of deterring a Soviet aggression. During the decade of cooperation with Russian analysts after the end of the Cold War we found out that, based on the results of war games and battle simulations, Soviet leaders concluded that the risk of not meeting the operational objectives of a successful attack on NATO was too high. Given Putin's revisionist policy, NATO's problem today is how to re-establish deterrence in an ever more complex environment characterized by cyber threats and hybrid warfare. Hopefully, modeling and simulation will again help stabilizing the situation.

Reiner K. Huber is Emeritus Professor at the Universität der Bundeswehr München (UniBwM – University of the German Armed Forces, Munich). He received his academic education from 1954 to 1960 at the Technical University of Munich (TUM) majoring in Mechanical and Aeronautical Engineering and, as a Fulbright Scholar, at the University of Texas majoring in Industrial Engineering. He then served as Technical Officer of the Luftwaffe for three years. In 1964 he joined the OR Group of Germany's newly founded defense support institution IABG as an analyst where he later became head of its Systems Studies Division. As part time research assistant at the TUM he received his Dr,-Ing (PhD) in 1970. In 1975 he was appointed Chair of Applied Systems Science and OR (with emphasis on defense and security issues) in the Department of Computer Science of UniBwM. There, he was dean and member of the Senate from 1981 to 1986. In 2000 he became Emeritus.

From 1971 to 76 he was a member of the NATO-Science Committee's Advisory Panel on OR (APOR) and the Special Program of Systems Science (SPOSS). He was visiting professor at the Naval Postgraduate School in Monterey, California in 1979 and 1983, and visiting lecturer at the Korean Institute of Defense Analysis in Seoul (1980), the Royal Military College of Science at Shrivenham (1985), and the Military Operations Research and Analysis Institute at the Academy of Military Science in Beijing (1988). He organized and led several international conferences on defense and security analysis and has been a long-time research associate of Vector Research in Ann Arbor, Michigan, and the RAND Corporation in Santa Monica, California, a consultant to NATO and the German Ministry of Defense and he is a Senior Fellow of the Potomac Foundation in Vienna, Virginia. In recognition of his cooperation with Russian analysts after the end of the Cold War he was elected associate member of the Russian Academy of Natural Science in 1995. His recent work is focused on Command and Control for complex endeavors.

MASM KEYNOTE

Tuesday, December 11, 3:30pm-5:00pm
R14

Reflections on Reference Modeling, Simulation Testbeds, and Reproducibility

Lars Mönch
Professor, University of Hagen, Germany

This presentation will discuss requirements for reaching the long-standing goal of designing a reference model for planning and control functions in semiconductor supply chains. A recently proposed simulation testbed for semiconductor supply chains will be described as an intermediate step towards reaching this goal. Some applications of the testbed will be presented. The discussion of the testbed will be related to recent initiatives for replicated computational results and in more general terms to reproducibility of scientific results and open research efforts.

Lars Mönch received the master's and Ph.D. degrees in Applied Mathematics from the University of Göttingen, Germany, and the Habilitation degree in Information Systems from the Technical University of Ilmenau. He is a Full Professor with the Department of Mathematics and Computer Science, University of Hagen, Germany. His current research and teaching interests are in production planning and control of semiconductor wafer fabrication facilities, applied optimization and artificial intelligence applications in manufacturing, logistics, and service operations. He has authored over 80 refereed journal papers and book chapters, two monographs, and one edited book. He serves as an Associate Editor for the IEEE Transactions on Semiconductor Manufacturing, the IEEE Transactions on Automation Science and Engineering, the European Journal of Industrial Engineering, Business & Information Systems Engineering, and the Journal of Simulation. He can be reached by email at Lars.Moench@fernuni-hagen.de.

Vendor Workshops & Tutorials

Sunday 10:00a.m.-12:00p.m.

VENDOR WORKSHOPS / R14

MathWorks

Hybrid Simulation for Scenario Modeling in MATLAB. Learn how to combine discrete-event simulation, state charts and time-driven dynamic systems in one model integrated with MATLAB using the Simulink platform. We will also show how to leverage MATLAB's data analytics capabilities for understanding simulation results and optimization.

VENDOR WORKSHOPS / R17

FlexSim

Automatic Pathfinding in FlexSim. FlexSim's automatic pathfinding tool, the AStar Module, uses the A* algorithm to find a path between multiple points. It enables users to set boundaries, barriers, and other rules in their modeling space—rules that operators and vehicles will then follow as their travel paths are automatically created. In this workshop, join FlexSim CEO Bill Nordgren as he covers how to use the AStar Module in various modeling situations.

Sunday 12:30p.m.-2:30p.m.

VENDOR WORKSHOPS / R14

Applied Materials

AUTOMOD® & AUTOSCHED®: Automation & High-Tech Modeling Solutions. Come learn about the AutoMod & AutoSched products by Applied Materials, their use and flexibility to solve real-world complex modeling problems. See for yourself why AutoMod & AutoSched have outlasted the competition for over 30 years. AutoMod's power lies in its performance, scalability and accuracy in detailed modeling of large and complex manufacturing, distribution, automation and logistic operations, leaving the competition behind. Understand why AutoSched is the only product of choice for modeling high-tech manufacturing environments that require complex product routings, sequence controls, and equipment qualifications enable scheduling, capacity planning, and preventive maintenance analyses.

VENDOR WORKSHOPS / R17

Rockwell Automation

Modeling Tool to Size Energy Efficient Manufacturing: Optimize Production While Minimizing Energy Consumption. Arena Simulation Software from Rockwell Automation has been the world-class solution for the top Fortune 500 companies for decades. Tech-Team utilizes the discrete simulation software for their customers business challenges. In this workshop, Tech-Team will share some of these projects and how they are taking the powerful tool to the next level with simulation. The Arena toolset allows even the most complex simulation requirements to be achieved. Join us for this informative session with Tech-Team.

VENDOR WORKSHOPS / R22+R23

Siemens

Build Your Own Simulation Model Using Plant Simulation. Take this opportunity to learn why so many of the world's largest manufacturers use Plant Simulation from Siemens to simulate and optimize their production processes. We intend this to be a "live" session where you get to run the software yourself after a quick introduction. Plant Simulation will run from a pre-installed USB memory stick that we will hand out to you so all you need is a Windows PC. Experience firsthand how fast and interactively you can design your 3D model, run experiments and get results even without any prior training. Along with the hands-on session, we will also present further possibilities, news in the software and perhaps some real industrial use-cases as well.

VENDOR WORKSHOPS / R18

Systems Navigator

Case Studies of Warehouse and Supply Chain. Systems Navigator is proud to present two compelling case studies, where with the help of our advanced discrete event simulation technology, our clients have been able to save money, increase customer satisfaction and reduce risk. Case study 1: New coil warehouse in the steel industry: describes a simulation model to analyze and optimize the logistics of a new coil warehouse for a large steel manufacturer. Using both our modelling & scenario management software, we were able to optimize the design of the new warehouse, resulting in a capacity increase of around 300 coils! Case study 2: Live supply chain model for marine module shipments: describes an operational supply chain model for a major international oil company (IOC). Combining the model, both during design as well as in operation, has resulted in maximized benefits for the client in terms of capital saved, risk management, contractor evaluations, as well as scenario planning.

Sunday 3:00p.m.-5:00p.m.

VENDOR WORKSHOPS / R24+R25

Evoma

Production Systems Analysis and Optimization using FACTS Analyzer. Factory Conceptual design Tools using Simulation (FACTS) Analyzer is a discrete-event simulation software developed in Sweden with the objective to promote manufacturing decision makers to play the role of simulation analysts, particularly in the early, conceptual system design phase. It features integrated support of simulation-based optimization, specifically using multi-objective optimization algorithms, to facilitate managers/engineers to run advanced optimizations to seek the optimal combinations of design variables to support more confident decision making for the design and improvement of production systems. It is also designed with the principle of rapid modeling to aid the users to build simulation models without the need of any programming skills. The concept of rapid modeling and integrated support of simulation-based optimization have facilitated FACTS Analyzer to be a unique and effective software for production systems analysis and improvement.

VENDOR WORKSHOPS / R14

Simio Simulation and Scheduling Software

New Innovations: Cloud Computing, Real-Time Scheduling, Industry 4.0, and More. With Simio leveraging the cloud computing power of Microsoft Azure to support your most demanding applications, its compatibility with Schneider Electric's Wonderware to allow detailed production scheduling with real-time data and risk analysis, and ability to schedule and reschedule in real-time, Simio is leading the way in Industry 4.0 and creating a digital factory. Outside our immense technology partner advances, we have great new features, application areas and capabilities! Come explore an overview of the new Simio experience and see why we are always "Forward Thinking."

VENDOR WORKSHOPS / R18

The AnyLogic Company

Material Handling Simulation with AnyLogic and AnyLogic Cloud. We will focus on AnyLogic's new features: The Material Handling Library, browser-based animation, and AnyLogic Cloud. After a quick tour around the AnyLogic model development environment and some demos of simulations running both in the software and in the Cloud, there will be a live model building session. We will build a factory floor model using the new Material Handling Library and also upload the it to AnyLogic Cloud. The model will be run with and without animation before finally setting up and running cloud-based Monte Carlo and Parameter variation experiments. We will then explain the benefits of cloud-based parallel model execution. At the end, as always, we will have time for Q&A.

VENDOR WORKSHOPS / R17

Xcelgo

Benefit from Simulations Throughout an Automation System's Lifecycle with Experior. With Industry 4.0 trends such as Smart Manufacturing, IoT and Digital Twins unfolding, the use of simulations throughout the lifecycle of automation systems is becoming increasingly relevant. Xcelgo's workshop will provide the audience with examples of beneficial simulation applications throughout an automation system's lifecycle and demonstrate several of these applications – on the basis of their own developed software platform for 3D modelling, simulation and emulation, Experior. The workshop also initiates a discussion of the benefits and disadvantages of a simulation platform solution versus a simulation software package solution. Among other things, the platform solution that Xcelgo offers will streamline the simulation process and pave the way for auto generation of simulation models.

VENDOR WORKSHOPS / R22+R23

ÅF

The Philosophy of Simulation - and How Our View of Simulation Shapes Our Models. The aim of this "workshop" is partly to inspire, partly to provoke, partly to challenge! We will discuss how we think related to simulation, how we use related competence (or don't), what demands we put on the software platforms (and don't), how we work in the projects (and don't), and what issues we address (and don't) – the "philosophy of simulation"! There will be a few presentations to start with, to set the platform – and hopefully inspire. Discussions and questions – also during presentations – are encouraged. There will be interactivity, through questions or "exercises". There will be a panel, to trigger debate and discussions. The message is, to summarize, that the potential of simulation is hugely underutilized! And the major obstacle is the profession itself! Do you agree? Or not? Please help us make this a worthwhile workshop!

Monday 10:00a.m.-11:30a.m.

VENDOR TUTORIALS / R25

FlexSim / SAS Simulation

Introduction to Simulation with FlexSim / Bill Nordgren (FlexSim Software Products, Inc.)

Join FlexSim CEO Bill Nordgren in a hands-on presentation where you'll learn how to build simulation models using FlexSim simulation software. FlexSim combines powerful statistical analysis with 3D visualization, allowing you to test "what if" scenarios in a risk-free virtual environment. You'll be introduced to FlexSim's powerful standard object library, which includes a variety of pre-built, customizable objects that you can drag and drop quickly and accurately imitate a real-world system—plus our vast array of logic-building and application-specific tools for any modeling situation. Stop by and see how FlexSim can help you get the most of your process improvement initiatives.

Looking Beyond the Model with SAS Simulation Studio: Data Input, Collection, and Analysis / Edward P. Hughes and Anup C. Mokashi (SAS)

Discrete-event simulation is regularly intertwined with many other forms of analytics. Source data often must be repaired or processed before being used to characterize variation in a simulation model. Collection of simulated data needs to coordinate with and support the evaluation of performance metrics. Or you might need to integrate other analytics into a simulation model to capture specific complexities in a modeled system. SAS Simulation Studio provides an interactive, graphical environment for building, running, and analyzing discrete-event simulation models, and is an integral part of the SAS analytic platform. We illustrate how SAS Simulation Studio helps you tackle each of these challenges. You have full control over the use of input data and the creation of simulated data. Strong experimental design capabilities mean you can simulate for all needed scenarios. Additionally, you can embed any SAS analytic program—optimization, data mining, or otherwise—directly into the execution of your simulation model.

Monday 1:30p.m.-3:00p.m.

VENDOR TUTORIALS / R25

Anylogic

New AnyLogic Material Handling Library / Pavel Lebedev and Nikolay Churkov (The AnyLogic Company)

The new AnyLogic Material Handling Library simplifies the simulation of complex manufacturing systems and operations. It can be used to design detailed models of production and storage facilities and manage material workflows inside four walls. The digital factory model, created with the material handling simulation toolkit, can help test and optimize production, transportation, and inventory policies, as well as reduce possible errors and material flow delays on the factory floor. In conveyor network models, created with the Material Handling Library, users can apply default or set up custom routing strategies for material items, industrial robots, manufacturing machines, and operators. Simulated AGVs and other transporters automatically avoid collisions, detect possible deadlocks, and resolve them.

AnyLogic Cloud — Cloud-based Simulation Analytics / Andrei Borshchev and Nikolay Churkov (The AnyLogic Company)

AnyLogic Cloud is a web service that allows users to run simulation models online on any device using just a web browser, and share the output results with colleagues and customers. It equips users with cloud-based simulation capabilities for setting up and running complex experiments, displaying results on custom dashboards, and providing online simulation analytics to clients. AnyLogic Cloud Subscription provides extended Cloud simulation capabilities with unlimited run time, additional computing resources, and access to external services. The open API functionality, available with the subscription, allows users to design custom web interfaces for simulation models. For companies subject to strict operating guidelines we offer AnyLogic Private Cloud. Its infrastructure can be hosted on-site, at company's data center, and integrated in company's workflows, so that AnyLogic models can be deployed throughout the company. The dedicated environment of the Private Cloud gives complete control over the data and its processing.

Monday 3:30p.m.-5:00p.m.

VENDOR TUTORIALS / R25

ExtendSim / Siemens PLM

Vehicles on Networks in Discrete Event Simulation / Guillaume Lagaillarde (1POINT2)

It is no mystery that mobility is one of the challenges society and industry have to face. Mobility is not only a issue for people. It is also a necessity for goods and any piece of material inside and outside factories. Without movement, no production. One of the most flexible way to move people or goods from one place to another is using Vehicles moving on networks. Sometimes the vehicle is just a human transporting an object. Yet, this essential function : calling a vehicle located in C to transport an object from A to B on a navigation network (often shared with other vehicles you don't want to collide) is not always present out of the box in standard discrete event simulation packages. ExtendSim, a great, affordable and flexible simulation toolbox is a good platform to develop such fundamental function. 1Point2 present its generic Vehicle on network ExtendSim library.

The Digital Twins of Product, Production and Performance / Johan Nordling and Gunnar Latz (Siemens PLM Software)

Siemens is a leading global provider of software solutions to drive the digital transformation of industry, creating new opportunities for manufacturers to realize innovation. This session will focus on two of our simulation solutions and we will mix product updates with industrial use-cases: Simcenter Amesim, that allows system simulation engineers to virtually assess and optimize the performance of mechatronic systems; and Plant Simulation, that allows users to model, simulate, explore and optimize logistics systems and their processes.

Tuesday 8:00a.m.-9:30a.m.

VENDOR TUTORIALS / R25

Simio / Systems Navigator

The Applications of Simio Simulation and Scheduling in Industry 4.0 / Renee Thiesing (Simio LLC)

Simulation has traditionally been applied in system design projects where the basic objective is to evaluate alternatives and predict and improve the long-term system performance. In this role, simulation has become a standard business tool with many documented success stories. Beyond these traditional system design applications, simulation can also play a powerful role in scheduling by predicting and improving the short-term performance of a system. In the manufacturing context, the major new trend is towards digitally connected factories that introduce a number of unique requirements which traditional simulation tools do not address. Simio has been designed from the ground up with a focus on both traditional applications as well as advanced scheduling, with the basic idea that a single Simio model can serve both purposes. In this paper we will focus on the application of Simio simulation and scheduling in the Industry 4.0 environment.

Optimizing Manufacturing and Supply Chains using Digital Twin Systems / Rienk Bijlsma and Daan Merkestein (Systems Navigator)

Systems Navigator is proud to present two compelling case studies of digital twin systems, where with the help of our advanced discrete event simulation technology, our clients have been able to save money, increase customer satisfaction and reduce risk. The first case study is about a simulation model for a new coil warehouse in the steel industry that is used for analysis & optimization of the layout. The final solution consists of a Simio simulation model, with a Scenario Navigator user interface. The second case study is about a simulation model for a live supply chain of marine shipments in the oil industry, that is used to design the supply chain, as well as predict possible future scenario's. This operational system runs on an Arena simulation model, and is operated through a Scenario Navigator user interface.

Tuesday 10:00a.m.-11:30a.m.

VENDOR TUTORIALS / R4

Arena

Scenario Analysis with Arena Simulation / Tyler DiFrischia (Rockwell Automation)

Arena Simulation Software from Rockwell Automation is used to analyze and compare scenarios to ensure the optimal configuration of business processes. Customers use this tool globally to make informed decisions and avoid wasteful spending. In this session, Rockwell Automation will review how they used Arena Simulation to develop a digital twin, analyze a production line, and cut down on change over times to meet customer demands. During the discussion, Rockwell will also introduce the newest features used to make this powerful simulation.

VENDOR TUTORIALS / R25

Experior / Mozart

Smart SCM Framework with Mozart / Keyhoon Ko (VMS Global, Inc.) and Seungyoung Chung and Byung Hee Kim (VMS Solutions. Co. Ltd)

Accurate production schedule is a key attribute to collaborate among supply chain and meet the due date. Based on current progress using IoT (Internet of Things) technology as well as MES (manufacturing execution system), a simulation-based planning and scheduling system mimics the real manufacturing system and generates reasonable results. Simulation may be a useful tool to solve complex process shedule like semiconductor manufacturing or tons of sub-parts such as ship building and offshore industry. MOZART has been implemented in semiconductor, display panel, and tire industries as a planning and scheduling system. It covers weekly planning (Master Plan: MP), daily

planning (Factory Plan: FP), and real time scheduling for these double-digit-day cycle time product manufacturing. MOZART extended the coverage to meet offshore project whose cycle time is several hundreds of days.

Using Modern 3D Modelling throughout the Lifecycle of Automation Systems with Experior / Bent Aksel Jørgensen (Xcelgo)

In the manufacturing and logistics industries, the use of 3D models of automation systems is becoming increasingly relevant. Traditionally, these industries only used simple simulations to support concept modelling in the early design phase as well as classic simulation in the decision-making process, but modern technology has given rise to the development of 3D modeling in new and exciting directions. Important game changers are virtual commissioning technologies and versatile 3D modelling software platforms that allows for custom 3D modelling tools and integration with company workflow. These technologies paves the way for control software testing prior to commissioning, realistic operator training, safe modifications and optimization during operation as well as handy retrofitting and refurbishment. This presentation presents the new modelling approaches and tools applied to support each stage of an automations system's lifecycle, and the System Lifecycle Management approach to integrate company workflow with 3D modelling.

Tuesday 1:30p.m.-3:00p.m.

VENDOR TUTORIALS / R25

MATLAB Simulink / ABS Platform

Agent-based Modeling Approach in MATLAB and Simulink for Autonomous Driving Scenarios / Guang-Lei Wang (The Mathworks), Teresa Hubscher-Younger (The MathWorks), and Wei Li and Fu Zhang (The Mathworks)

Using different new features in MATLAB and Simulink, we will show how to model autonomous driving scenarios with an agent based modeling approach. ABM is a popular simulation approach for autonomous driving scenarios, e.g. in developing driving policies and safety verification. The conventional motion planning and control methods, e.g. PID control, feedback linearization or model predictive control, expect a prediction over the future trajectories of other traffic participants to avoid collisions. However, actual traffic scenarios involve complicated interactions between drivers (Schwarting, Alonso-Mora and Rus, 2018). To conquer this challenge, the emerging trends are the behavior-aware motion planning and learning-based approaches. ABM could then be exploited to handle the complex environments, while modeling the uncertain interactions with each other. Schwarting, W., Alonso-Mora, J., and D. Rus. 2018. "Planning and Decision-Making for Autonomous Vehicles" In Annual Review of Control, Robotics, and Autonomous Systems. Vol. 1, 2018, pp. 187–210.

Self-evolving Agent-based Simulation Platform for Predictive Analysis on Socio-Economics by using Incremental Machine Learning / Dong-oh Kang, Jang Won Bae, Chun-Hee Lee, Joonyoung Jung, and Euihyun Paik (Electronics and Telecommunications Research Institute)

We have developed a self-evolving agent-based simulation platform for predictive analysis of socioeconomic applications. Although continuous model correction is required for reliable prediction whenever new data is added, it is very time-consuming and expensive to repeat the new modeling and calibration tasks of the agent-based socioeconomic simulation applications. We have developed algorithms, software architecture and tools to evolve the agent-based models in an incremental way of data assimilation and automatic model calibration with minimized human intervention via machine learning. We use a changeable component-based structure of agent-based models and the Gaussian optimization technique to derive optimal model configurations from incoming data. Also, we have developed a distributed and parallel simulation engine for large-scale simulation and a web-based GUI tool that manages the simulation and displays results. We will demonstrate the self-evolving process and results of simulation tasks of the Korean housing market and welfare of the elderly with real data.

VENDOR TUTORIALS / R24

Simulation-based Management / Digital Twins

Simulation-based Management (SBM) – Various Examples / Stefan Bengtsson (ÅF)

ÅF packages a major portion of the simulation-related services under the headline SBM. Focus is to convey a more all-embracing view of how simulation competence can and partly should contribute, quite simply by asking the question: "Can we add value in real life, compared to the alternative – not using simulation competence?". Examples from the healthcare sector are used to illustrate, both on macro, meso and micro levels of abstraction. Here models of hospitals-to-be, whole county total care need, and more operational systems will be shown and briefly commented. A combination of Discrete Event and Agent Based modeling is the rule, but based on the philosophy of having a Paradigm-Free approach. Simulation competence should be seen as one of the strongest means to handle change management, decision-making, and general managerial challenges! And it should be considered the by far best way to support system understanding and thinking!

Learnings from 20+ Digital Twins / Lars C. Jacobsen (NIRAS A/S)

Learnings from 20+ Digital Twins. Building a usable Digital Twin is a multi-disciplinary task. It requires the combined knowledge of operations research, statistics, supply chain management, domain knowledge, programming, virtual reality, data structures and data structuring, programming, drawing and project management. So is it possible to build a useful Digital Twin with a reasonable effort and what should students learn?

Tuesday 3:30p.m.-5:00p.m.

VENDOR TUTORIALS / R25

Automod / FACTS Analyzer

Automod: Material Handling Companies Product of Choice – Come See Why/ Daniel Muller (Applied Materials, Inc.)

AutoMod's capability to model large complex automation and material handling systems continues to lead the market. Recent enhancements to AutoMod's material handling systems have increased modeling accuracy and ease-of-use. These advances have made AutoMod one of the most widely used simulation packages. AutoMod's power lies in its performance, scalability and accuracy in detailed modeling of large and complex manufacturing, distribution, automation and logistic operations, leaving the competition behind. Come see why the top material handling companies, high-tech companies, and systems integrators rely on AutoMod to deliver their results!!

Production Systems Analysis and Optimization Using FACTS Analyzer / Amos H.C. Ng and Jacob Bernedixen (Evoma AB)

Factory Conceptual design Tools using Simulation (FACTS) Analyzer is a discrete-event simulation software developed in Sweden with the objective to promote manufacturing decision makers to play the role of simulation analysts, particularly in the conceptual design phase. It features integrated support of simulation-based optimization, specifically using multi-objective optimization algorithms, to facilitate managers/engineers to run optimizations to seek the optimal combinations of design variables to support confident decision making for the design and improvement of production systems. It is also designed with the principle of rapid modeling to aid the users to build models without the need of any programming skills. The concept of rapid modeling and integrated optimization support have facilitated FACTS Analyzer to be a unique and effective tool for production systems analysis and improvement. In this presentation, we will go through six features which make FACTS Analyzer special when compared to other simulation software available in the market.

VENDOR TUTORIALS / R24

Industrial Path Solutions / INCONTROL

Demonstration of Simulation Software Industrial Path Solutions (IPS) / Tobias Forsberg, Peter Mårdberg, Roland Roll, Erik Rilby, and Johan S. Carlson (Fraunhofer Chalmers Centre for Industrial Mathematics)

IPS is a math based software tool for automatic verification of assembly feasibility, design of flexible components, motion planning and optimization of multi-robot stations, and simulation of key surface treatment processes. IPS successfully implements the potential of the virtual world. IPS is developed by Fraunhofer-Chalmers Centre and Fraunhofer ITWM, and distributed by IPS AB and fleXstructures GmbH.

Simulation: Contributing to Insights and Performance Improvement? / Louis Schijve, Fred Jansma, and Frank van Poeteren (INCONTROL Simulation Software)

Information Technology is inextricably linked to virtually all Business processes. And that is exactly where INCONTROL Simulation Software positions its Simulation Software Platform: Enterprise Dynamics. Enterprise Dynamics enables organizations to innovate and improve their business processes e.g. during project preparation & implementation and as an integral part of business operations. At WSC we share our vision, technology insights and business cases on how simulation improved the performance of our clients. INCONTROL Simulation Software is integrated in curricula at Universities, Applied Sciences and R&D Institutes. Together with these partners we implemented solutions in the Process Industry, Transportation, Logistics, Crowd Management and Public Safety.

Final Program Abstracts

Sunday 1:00p.m.-2:00p.m.

PHD COLLOQUIUM / J2

PhD Colloquium Keynote: Stewart Robinson
Anastasia Anagnostou (Brunel University London)

Are You Building and Using the Best Model? / Stewart Robinson (Loughborough University)

Simulation models provide a powerful means for representing, understanding, and improving the real world. But how do you know that you are building and using the best model? As modelers and analysts we tend to focus on model accuracy as a means for improving the chances that a model is valid. We assume that a more accurate model and set of results is better, and, therefore, is more likely to be believed and acted upon. But is this assumption true? Does the credibility of the results depend upon the accuracy of the model? Can a wrong model still be useful? In this talk we shall explore the relation between accuracy, validity, credibility, and usefulness. If our ultimate aim is to provide analyses that are useful, this may challenge our assumptions about what is the best model.

STEWART ROBINSON is Dean and Professor of Management Science at Loughborough University, School of Business and Economics. Previously employed in simulation consultancy, he supported the use of simulation in companies throughout Europe and the rest of the world. He is author and co-author of six books on simulation. His research focuses on the practice of simulation model development and use. Key areas of interest are conceptual modelling, model validation, output analysis, and alternative simulation methods (discrete-event, system dynamics, and agent-based). Professor Robinson is co-founder of the Journal of Simulation and the UK Simulation Workshop conference series. He was President of the Operational Research Society (2014-2015). His home page is www.stewartrobinson.co.uk and his email address is s.l.robinson@lboro.ac.uk.

Sunday 2:15p.m.-3:45p.m.

PHD COLLOQUIUM / J2

Presentations - I
Anastasia Anagnostou (Brunel University London)

Pipelines and their Compositions for Modeling and Analysis of Controlled Online Networked Social Science Experiments / Vanessa I. Cedeno-Mieles (Virginia Tech; Escuela Superior Politécnica del Litoral, ESPOL)

There has been significant growth in online social science experiments in order to understand behavior at- scale, with finer-grained data collection. Considerable work is required to perform data analytics for custom experiments. We also seek to perform repeated networked experiments and modeling in an iterative loop. In this work, we design and build four composable and extensible automated software pipelines for (1) data analytics; (2) model property inference; (3) model/simulation; and (4) results analysis and comparisons between experimental data and model predictions. To reason about experiments and models, we design a formal data model. Our data model is for scenarios where subjects can repeat actions (from a set) any number of times over the game duration. Because the types of interactions and action sets are flexible, this class of experiments is large. Two case studies, on collective identity and complex contagion, illustrate use of the system.

Bringing Together Lean, Simulation and Optimization in a Framework for System Design and Improvement / Ainhoa Goienetxea Uriarte (University of Skövde)

Is it beneficial to combine lean, simulation and optimization? And if so, how can they be combined for decision-making support in system design and improvement? This research proposes a framework that sets the basis for achieving beneficial interactions between the lean philosophy, methods and tools, and simulation-based optimization. A framework that gives the users the possibility to get better system understanding, conduct a deeper system analysis, and attain

an optimal system design and improvement, and thereby get better foundation for sustainable long time improvement. The framework has been tested in several real-world case studies. Moreover, surveys have been conducted to evaluate the perception of subject matter experts about its usefulness, as well as its usability and perceived quality by end users and decision makers, all of them reporting very positive results.

A Hybrid Systems Approach using Real-Time Data and Computer Simulation: A Research Framework and its Implementation in the Context of Urgent and Emergency Care / Alison Harper (University of Exeter)

This study aims to investigate how real-time simulation can support short-term decision-making in urgent and emergency care. A hybrid systems modelling approach is proposed, which is the combined application of real time-data feeds, forecasting and simulation. This is encapsulated in a research framework, which proposes a step-by-step approach to inform the development of a real-time simulation. The framework is implemented through a case study that focuses on the urgent care network in Torbay and South Devon; it relies on the NHSquicker platform for real-time data feeds. Conventional simulations rely on historic data, but with the advent of technologies associated with business intelligence and data sciences, it is now possible to process and store an increasing volume and variety of data, including high-velocity and real-time data. With open architectures and standards for data sharing, this data is increasingly available for data-driven applications which may run, for example, prediction algorithms or visualizations.

Improving Make-ahead Chemotherapy Drug Policies at Outpatient Infusions Centers / Donald Richardson (University of Michigan)

During an outpatient chemotherapy infusion visit, patients typically have blood work done, see their oncologist in the clinic, wait for the pharmacy to prepare their drugs, and receive their infusion. The time variability at each of these steps can introduce delays, which not only negatively impact the patient but propagate through the system to negatively impact other patients and staff as well. One major opportunity to reduce patient waiting time is by pre-mixing (i.e. making drugs before the patient arrives for their infusion appointment) at the pharmacy. This, however, requires careful consideration of the trade-off between time savings versus the potential cost of wasting a drug if the patient is deemed ineligible for treatment on the day of their appointment. We present a prediction, optimization, and discrete-event simulation model to improve make-ahead drug policies utilizing data from our collaborators at the University of Michigan Rogel Cancer Center (UMRCC).

Development of a Generic System Dynamics-Discrete Event Simulation Hybrid Modelling Framework / Omogbai Oleghe (Cranfield University)

The field of System Dynamics-Discrete Event Simulation (SD-DES) hybrid modelling is fragmented with no standardized or structured format for framing a SD-DES hybrid modelling-based study. This work develops a SD-DES hybrid modelling framework to address the research gap. The developed SD-DES hybrid modelling framework is one where the modelling process is an iterative and interactive one that evolves as the hybrid is developed, making it simple, straightforward and ame-nable to a variety of systems and problem situations.

Can We Learn from Wrong Models? An Experimental Study on Learning from Oversimplified Simulation Models / Naoum Tsioptsias (Loughborough University)

Simplifying a model is a necessity in order to create it, but extreme simplification can lead to a wrong - inaccurate or unrepresentative - model. If we end up with such a model, can we still learn from it? This paper investigates possible usefulness and learning outcomes from using wrong models in Simulation. An experiment comparing learning of a model of two different fidelity levels - oversimplified and adequate - is set on a pre/post test basis utilising a psychological framework to measure differences within two groups of students. The results suggest that users of the oversimplified version managed to gain a similar level of learning to those using the adequate, while they denoted their model as wrong but still useful for their tasks. Future work will tackle the factors that constitute to creating wrong models and wrong model uses in practice by interviewing simulation experts.

Dynamic Generation of a Sparse Forest Biomass Origin Points Network / Mika Aalto (Lappeenranta University of Technology)

Forest biomass supply is scattered spatially and temporally. To have a realistic supply simulated by agent-based model, spatial analysis of supply is improved to include dynamic elements with stochastic distribution. The annual theoretical supply is obtained from static biomass database and it is allocated to the grid of supply points. To have realistic transport distances to demand point, the grid should be dense, but this generates too many points. There for a limited number of points are selected and the supply of these points are increased. The use of this model obligates the selected supply points being the same between runs having stochastic elements for other operations. With 2 km x 2 km grid and 120 km radius supply area feedstock volume and transportation distances were corresponding with real life conditions.

A Discrete Event Simulation Model to Test Multimodal Strategies for a Greener and More Resilient Wood Supply in Austria / Christoph Kogler (University of Natural Resources and Life Sciences, Vienna)

Increasing occurrence of natural disturbances such as windstorms and high snow cover as well as uncertainty according to queuing and lead times, bottlenecks, utilization, stock level, wagon and truck availability and machine breakdowns lead to supply chain risks and seasonal irregularities in wood harvest and transport. Innovative multimodal systems via rail terminals offer the potential to increase buffer capacity and to reduce greenhouse gas emissions. Therefore, a train terminal is included in a new virtual environment spanning the whole wood supply chain and enabling manager involvement in testing, analysis and evaluation of a complex multimodal system. The simulation model facilitates carrying out experiments and scenario designs for strategy comparisons in workshops with supply chain managers and provides intuitive decision support by animation and a KPI-cockpit. Adapting collaborative supply chain control strategies in participatory simulation enhances the development of advanced risk management and therefore improves supply chain resilience, efficiency and sustainability.

Green Simulation Optimization using Likelihood Ratio Estimators / David J. Eckman (Cornell University)

In the setting of repeated simulation experiments, reusing past outputs to make current and future experiments more efficient is referred to as green simulation. Green simulation estimators can be naturally extended to simulation optimization, with outputs from past iterations of a search being reused in subsequent iterations to estimate the objective and gradient. However, for simulation optimization searches that identify new designs based on past outputs, outputs from different iterations are conditionally dependent given the visited designs. This conditional dependence violates a key assumption used to establish the unbiasedness of green simulation likelihood ratio estimators. We explore the consequences of the resulting conditional bias on the behavior of gradient-based optimization algorithms that use green simulation estimators.

Modelling and Generating Nonhomogeneous Poisson Processes using a Spline Function / Lucy E. Morgan (Lancaster University)

Approaches to modelling nonhomogeneous Poisson processes (NHPPs) commonly use piecewise representations of the rate function. In reality, real-world rate functions are unlikely to take a piecewise form and therefore bias is introduced. We propose a spline function representation using a large number of knots. The resulting function, being both smooth and highly flexible, is able to take on a wide variety of functional shapes reducing the bias between it and the true process. Due to the added flexibility we control overfitting, and thus variability, by adding a penalty to the NHPP log-likelihood. Our approach optimizes the spline coefficient and penalty parameter combination by minimizing a modified AIC score. Our approach also leads to a simple method for arrival generation from the resulting spline function.

Linking Simulation Conceptual Modeling to Construction Planning: A Last Planner® Driven Approach / Mohammed Adel Abdelmegid (The University of Auckland)

The Conceptual Modeling (CM) phase of simulation studies encompasses the thinking process of how a simulation model should be developed, how it relates back to the real system, and what decisions can take place to shift system performance towards the intended one. In a project management context, CM

incorporates the planning phase of simulation projects. This study explains how simulation CM can be integrated with the Last Planner® System (LPS), which is considered the most established lean-based construction planning method. This integration is accomplished by presenting a combined CM/LPS framework that matches elements of CM with the LPS. On the one hand, the integrated CM/LPS framework aims at utilizing the time and effort of the LPS to build the conceptual model. On the other hand, CM can help improve the practices of the LPS by promoting creativity and problem-solving.

Improving Capacity and Resource Distribution in Police Custody / Heather Alexandra Callaghan (Loughborough University)

This PhD project is centered around developing strategies that can improve the resource distribution and, consequently, the capacity in UK custody suites. The budget cuts and lack of resources that UK police forces have been facing have been widely publicized and police custody is no exception.

Supporting Agent-based Modeling and Simulation in Demography / Oliver Reinhardt (University of Rostock)

Continuous-time microsimulation is an important method for predicting demographic changes in the next decades. However, these modeling and simulation studies face various challenges. One is to integrate adequately dynamics at different organizational levels, i.e. at micro level (e.g., individuals), and at macro level (e.g., population), and linking those dynamics in continuous time and discrete space. With more expressive models, demography has started moving from data- to hypothesis-driven development of individual-based models, which impacts modeling and simulation processes and methods used. This work aims at addressing various challenges of continuous-time agent-based simulation in demography.

Sunday 3:30p.m.-5:20p.m.

POSTER / K1

Poster Flash Presentations
Masoud Fakhimi (University of Surrey)

Managing Provenance of Simulation Studies / Pia Wilsdorf, Andreas Ruscheinski, Marcus Dombrowsky, and Adelinde M. Uhrmacher (University of Rostock)

Various workflow tools for simulation studies exist that also support reuse and reproducibility, e.g., by tracking provenance information and representing it using a provenance graph. However, depending on the level of granularity, the resulting graph may become enormous in size which makes it difficult for users to draw conclusions directly from the tracked information. Therefore, we employ a variety of aggregation techniques to manage the provenance information based on user requirements. Using a typical simulation case study we discuss applicability and effect of the different reduction techniques.

SPartAN: A Meta-algorithm for Reinforcement Learning using State Partitioning and Action Network / Kyohong Shin and Taesik Lee (Korea Advanced Institute of Science and Technology)

Targeting finite-horizon Markov Decision Process problems, we propose a novel approach with an aim to significantly enhance the scalability of reinforcement learning (RL) algorithms. Our approach, which we call a State Partitioning and Action Network, SPartAN in short, is a meta-algorithm that offers a framework an RL algorithm can be incorporated into. Key ideas in SPartAN are threefold: reducing the size of an original RL problem by partitioning the state space into smaller compartments, using a simulation model to directly obtain values of the terminal states of the upstream compartment, and constructing a quality heuristic policy in the downstream compartment by an action network to use in the simulation. Using temporal difference learning as an example RL algorithm, we show that SPartAN is able to reliably derive a high quality policy solution. Through empirical analysis, we also find that a smaller downstream state subspace in SPartAN yields higher performance.

A Simulation-based Study of Thermal Power Plant using a Fluid Dynamic Model and a Process Simulation Model / Teruaki Ito (Tokushima University)

The role of thermal power plants is becoming critically important in Japan because of the reducing number of nuclear power plants after Tohoku Pacific Ocean Earthquake. Renewable energy supply is expected as an alternative in terms of energy security but it is difficult to secure the energy in a very stable manner. As a result, unexpected demands on thermal power generation irregularly happen to cover the fluctuation of power supply and/or demand. Under these circumstances, the usage of thermal power plant equipped with a coal-fired boiler is changing towards a more dynamic and complicated manner of operation. This research conducted a study with the two types of simulation models to clarify this operation; namely, a fluid simulation model of coal-fired boiler; and a process simulation model of thermal power plant. This paper shows these two types of modeling approaches and discusses the feasibility of the models implemented in this study.

Salabim: Open Source Discrete Event Simulation and Animation in Python / Ruud van der Ham (salabim.org)

Salabim is a new open source object-oriented package specially developed for discrete event simulation of complex control in logistics and production environments. The choice of Python as the host language means that simulations can be easily combined with powerful packages for statistical processing and presentation, web interfaces, machine learning, databases, etc. The package is built on the solid foundations of the process approach as demonstrated in Simula, Prosim and Tomas. One of the key features of salabim is the integrated animation engine. The package can be used for a wide range of simulation applications, such as (air)ports, hospitals, warehouses, job shop production, distribution systems and communication networks.

Decision Support Tool for Demand Responsive Transport through Simulation / Sergei Dytckov, Paul Davidsson, Johan Holmgren, and Jan Persson (Malmö University, K2 - The Swedish Knowledge Centre for Public Transport)

Demand Responsive Transport (DRT) is seen as a means to providing mobility for passengers living in low density population areas and impaired passengers with a reasonable cost. Conventional public transport is too expensive to provide a desired level of mobility for these categories of passengers. Hence DRT has been introduced in order to replace or supplement existing transportation schemes. However, multiple DRT schemes were discontinued due to a high cost or poor patronage. In this work we argue that a simulation tool is required to analyze DRT applicability in given conditions before implementing it. As a first step towards this tool, we describe the requirements that DRT impose on a simulator.

Stochastic Modeling and Bayesian Inference of National Scale Epidemics in the Swedish Cattle Network / Robin Eriksson (Uppsala University)

In this work, we study the spread of a verotoxigenic E. coli in the Swedish cattle population and parameterize a disease-spread model by combining the high-performance simulator SimInf with actual agent transport and bacterial testing data. We perform Bayesian inference by using Approximate Bayesian Computations (ABC) and Synthetic Likelihood Markov chain Monte Carlo (SLMCMC), and we obtain posterior parameter densities with desirable averages.

Incredulous Scandinavians: An Agent-based Model of the Spread of Secularism / Ivan Puga-Gonzalez and LeRon F. Shults (University of Agder), Wesley J. Wildman (Center for Mind and Culture), and Saikou Diallo (Old Dominion Universtiy)

Here we describe an agent-based model of secular and religious worldview changes, the computational architecture of which is grounded in literature on the role of credibility enhancing displays (CREDs) in shaping the prevalence of supernatural beliefs in a population. Other methods have demonstrated that individuals who experience high exposure to religious CREDs are more likely to report religious beliefs and affiliation later in life. In contexts lacking in religious CREDs, religious worldviews tend to diminish over time. Agents are initialized with a variable worldview, ranging along a naturalist-supernaturalist continuum, and personality variables that influence preferences for joining secular or religious worldview groups. Both worldview and membership can be impacted by the intensity and consistency of CREDs in the environment. Our model explores the conditions under which religion fades within an arti-

ficial society that is designed to simulate contexts such as those populated by inCREDulous Scandinavians.

Comparing Multidisciplinary Optimization Architectures with an Aircraft Case Study / Brian Chell, Steven Hoffenson, and Mark R. Blackburn (Stevens Institute of Technology)

This research describes a comparison study of different ways to formulate and solve a Multi-Disciplinary Optimization (MDO) problem. Two MDO architectures, multidisciplinary feasible (MDF) and interdisciplinary feasible (IDF), were tested on a simulation-based aircraft model. The aircraft's aerodynamic performance is modeled with computational fluid dynamics, and its structure is modeled with finite element analysis. The results show that the MDF architecture finds better solutions when it comes to optimality, but it requires more computing resources, time, and has higher variability than IDF.

Development and use of a Multi-Actor Simulation Environment for Dutch Railways / Stan Albers (NS Reizigers BV), Julia Lo and Emdzad Sehic (ProRail), and Cor van 't Woudt (NS Reizigers BV)

As part of future railway infrastructure and timetable changes in the Netherlands, a multi-actor simulation environment is used to test concepts of train operation. In this environment, different operators can use their real-life or simulated control systems that are connected to a microscopic simula-tion of the timetable, infrastructure and safety system. In the poster session, a recent case will be highlighted, i.e. the investigation of a frequency increase of trains in 2018 on the Amsterdam – Utrecht – Eindhoven corridor. On this heavily used trajectory the frequency of intercity trains has been increased to run one intercity train every ten minutes. The goal of the simulation sessions is to allow operators to explore the impact of risks, to provide input and feedback, and to let them familiarize themselves with new concepts. Four simulation days were organized with about fifty persons involved as participants, actors, facilitators and observers.

Illegal Fishing and Trafficked Labor: An Examination of Policies to Address the Intersection of Prosperity and Exploitation / Renata Konrad and Khalid Saeed (Worcester Polytechnic Institute) and Matt Kammer-Kerwick (The University of Texas at Austin)

Human exploitation in the seafood industry is a complex transnational problem jeopardizing human rights and marine ecosystems. Labor trafficking, environmental sustainability, aquaculture, and socio-economic development interact interdependently, and form a large system with multiple decision makers with conflicting goals. We present the results of a System Dynamics simulation model which incorporates resource management of fish stocks and illicit labor markets. Using this model we examine the implications on trafficked labor of several policies including: imposing an excise tax, trafficking prevention campaigns, and increased policing.

Simulation Modelling for the Implementation Appraisal of Cardiovascular Device Implants / Samuel Omoniyi (University of Exeter)

Aging population and changes in lifestyles have increased incidents of cardiovascular diseases in the UK. Where drugs cannot provide effective treatments for these chronic diseases, Cardiovascular Implanted Electronic Devices (CIEDs) serve as alternative treatments for patients. But implant implementations have significant impact on patients and healthcare resources. Simulation modelling can support the clinical and healthcare operational management decisions connected to the implant processes. The appraisal of the operational requirements for implementing these implants would examine the impact of the intervention on hospital resources and the evaluation of their applicability during patient selection processes. An effective appraisal of implant implementation would ensure that stakeholders can make better decisions to enhance the effectiveness and efficiency in healthcare resource management. Hybrid of systems dynamics and agent-based modelling would be used to investigate many of the decision uncertainties arising from the complexity of a typical hospital system involved with this healthcare intervention.

Inequality, Famine, and Counter-measures: Teaching Agent-based Simulation as a Social Analysis Method / Jan Ole Berndt, Colja A. Becker, and Ingo J. Timm (Trier University)

This paper reports on agent-based simulation as a social analysis method. It describes the goals, scenario, tasks, and the modeling procedure of a teaching example for understanding effects of inequality in the context of the Irish famine of 1845–52. Furthermore, it outlines further research questions resulting from the authors' experiences with teaching modeling and simulation for social analysis.

Simulating Sudden Refugee Influx and its Impact on Demographic Structure: The Korean Case / Karandeep Singh (ETRI)

The problem of low fertility rate in a country gives rise to numerous other social and economic problems. Many solutions have been proposed for overcoming this issue, and immigration is one of the proposed solutions which may also entail opening up country for refuge, due to some unfortu-nate incidents in other countries. Working on these lines, we simulate the impact of rapid immigra-tion influx on fertility rates in Korea, using real data and agent based modeling.

The Impact of Monetary Policy on Financial Stability: Using an Agent-based Model to Explain Rebound Effects / Florian Peters (University of Rostock, Institute of Computer Science) and Oliver Reinhardt and Adelinde M. Uhrmacher (University of Rostock)

Since the financial crisis 2007, financial stability has come into the focus of central banks and the associated monetary policy. The impact of monetary policy on financial stability is dependent on financial market and inflation expectations which influence the behavior of a variety of agents in financial markets and in the real economy through the so called monetary transmission channel. These expectations of agents are mutually dependent and trigger rebound or spillover effects for every single monetary policy decision. Hence, understanding the dynamics of rebound effects is crucial to stabilize the economy. To get a better understanding of how monetary policy determines financial stability, we develop a sophisticated agent-basedmodel that mimics the entire monetary transmission mechanism.

Assessing the Potential of Case Managers in Emergency Departments by use of Discrete-event Simulation / Lien Vanbrabant (UHasselt)

Emergency departments (EDs) are continuously exploring opportunities to improve their efficiency. A relatively new opportunity, which has proven to be effective in other service systems, lies is the application of a case manager approach to ED physicians. By using dedicated physicians, putting a limit on the number of patients simultaneously assigned to a physician, and determining appropriate priority rules for assigning patients to physicians, throughput may be increased. The potential of applying a case manager approach in an ED is tested by use of a realistic simulation model based on the ED of a Belgian university hospital.

Simulation-assisted Decision Making for Supply Chain Disruptions in Production Control / Dennis Bauer and Andreas Schlereth (Fraunhofer Institute for Manufacturing Engineering and Automation)

Supply chain disruptions with an unpredictable occurrence such as significant differences between forecasts and actual customer demands are challenging for semiconductor manufacturers. Normally, these events are responded to with a time-consuming mostly manual procedure. This work describes an approach for an automated framework to react faster and with less effort on these unpredictable events. Within this framework simulation is necessary for the evaluation of automated decisions. Therefore, a discrete event simulation and a simulation based on a system dynamics approach have been combined. As a result of this framework's approach, safety stocks can be reduced due to a more accurate cycle time prediction and a reduced number of false alarms regarding supply chain disrup-tions.

Initial Sampling using Multi-Fidelity Information in Simulation Optimization of Manufacturing Systems / Ziwei Lin (Shanghai Jiao Tong University), Andrea Matta (Politecnico di Milano), and Shichang Du (Shanghai Jiao Tong University)

High-fidelity models are capable of providing accurate estimates but slow in execution. On the other hand, estimates provided by low-fidelity models are biased but fast. The knowledge embedded in low-fidelity models might be

helpful for simulation optimization algorithms. Several multi-fidelity modeling algorithms have been proposed in literature, whereas currently only high-fidelity information is used in the initial sampling phase. This poster provides an algorithm to allocate high-fidelity budgets using multi-fidelity information in order to contain a fixed number of good solutions in the initial design. Results show that the proposed sampling policy can allocate more budgets in promising areas.

Systematic Analysis of Micro Dynamics in Agent-based Simulation / Shohei Yamane, Hiroaki Yamada, Kotaro Ohori, and Hirokazu Anai (Fujitsu Laboratories Ltd) and Shuntaro Sakai, Kugo Takahashi, Jumpei Ouchi, and Shingo Takahashi (Waseda University)

Micro dynamics analysis in agent-based simulation plays an important role when the simulation is used for decision making in social systems. Since the analysis has been carried out through trial and error of analysts, its quality highly depends their skills and it is impossible to find out all significant relationships between macro phenomena and agent behavior. This paper proposes a novel analysis methodology not dependent on individual skills in order to investigate agent behavior systematically. By the methodology, analysts can generate meaningful hypotheses to explain a target macro phenomenon based on the agent behavior. We verified the effectiveness of our proposed methodology with the simulation of checkout area in a supermarket and showed that the method can generate hypotheses including the findings that were obtained by a specialist in agent-based simulation.

Capturing Emergent Behavior within the DEVS Framework / Daniel Foguelman (University of Buenos Aires) and Rodrigo Castro (Universidad de Buenos Aires)

Analyzing complex adaptive systems is a challenging task. Nature and its governing rules do not always present clear patterns. The hypothesis of emergent properties in such systems is hard to formulate and complex to infer. In this context, a great effort is being done by the Modeling and Simulation (M&S) community towards modeling emergent behavior. Our research proposes minimal modifications into the Discrete Event System Specification (DEVS) M&S framework that brings the detection of emergent behavior into the loop of a DEVS simulation. Novel behavior is encoded into the DEVS layered structure bridging the macro and micro levels. A proof of concept was implemented for the canonical Boids model.

Cloud-based Modeling and Simulation: Introducing the Distributed Simulation Layer / Nura Tijjani Abubakar (Brunel University London)

Many applications including Modeling and Simulation packages require automatic resource allocation and scalability features found in most cloud infrastructures. However, this comes at a usually high cost of investment from small, medium or even large enterprises. The technology gets more complicated when demand exceeds the supply of the needed computing resources while serving end-users at the optimum quality of service (QoS) such as performance, security, reliability, and interoperability. This research proposed a new cloud architecture with Distributed Simulation Layer atop the Microservice-based Cloud Application-level Dynamic Orchestration (MiCADO) framework. It will allow geographically distributed models with access to the high-performance computing resources needed for automatic scalability. The paper also talks about the simulation model interoperability standards suitable for making the new architecture widely adaptable.

Integrating Scientific Workflow to Science Gateway – an Exploration of Science Gateway Architecture for Distributed Simulation / Chukwudi Nwogu (Brunel University London)

The modelling and simulation (M&S) community is faced with the complications of developing distributed simulation (DS) and gaining access to distributed computing infrastructure (DCI) for speeding up simulation experimentations and manipulating the resultant data output. There is also the challenge of widely disseminating DS modules or their outputs to support decision-making and collaboration within operational research and management science (OR/MS). Science gateways (SGs) could alleviate these challenges. Therefore, this work will review the architectures of integrating scientific workflows (SWF) to SGs, as a means of adopting a suitable architecture for SG for DS.

An Interoperability Model for Collaborative Development of Distributed Supply Chain Simulations / Juan Leonardo Sarli (CONICET UTN)

Development of a collaborative distributed supply chain simulation implies interoperation of heterogeneous systems. Interoperability among several independent systems requires mutual understanding and meaning of shared data represented in a common structure. These two requirements are always a real challenge. In a High Level Architecture (HLA) based supply chain simulation, the federation object model (FOM) performs as a contract where mutual understanding and shared information are described. However, this contract is usually established manually and then the consistency and completeness cannot be guaranteed. Developing FOM and modifying existing systems to comply with the FOM implies a significant amount of time and effort which reduce the benefits of system reuse. This paper presents a heavy-weighted ontology-based method to construct interoperation models of HLA based supply chain simulation in a human-friendly, efficient, consistent and complete way. Besides, this method provides support to collaboration among several organizations of a supply chain.

MCMC Convergence Diagnostics via Regeneration with Application to the Bayesian Lasso / Yi-Lung Chen and Zdravko Botev (University of New South Wales)

MCMC techniques are popular solutions to approximate quantities that are difficult to compute exactly. Unfortunately, despite its wide use across various fields, most Markov chain samplers lack theoretically justified methods to analyze their output. That is to say, most MCMC samplers lack a) a consistent variance estimator for a given ergodic average; and b) an estimator for the total variation distance between the distribution of a draw from the Markov chain sampler and its target distribution. In this study we demonstrate how one can systematically address a) and b) by exploiting the underlying regenerative structure of the simulation output. Roughly speaking, regenerative structure are the times when a stochastic process (in this case a Markov chain) scholastically 'restarts' itself. Intuitively, if a Markov chain frequently 'restarts' itself, it should have a fast convergence hence, one may examine the convergence of a Markov chain sampler by identifying these events.

An Uncertainty Calibration Method for Multi-output Model / Xiaobing Shang, Ju Huo, Tao Chao, Ping Ma, and Ming Yang (Harbin Institute of Technology) and Bo Liu (China Shipbuilding Industry Corporation)

A comprehensive framework, combining the cumulative distribution function and modified Kolmogorov–Smirnov test, is proposed to solve multi-output simulation model's parameter calibration problem with the presence of uncertain parameters. The framework is based on comparing the difference between joint cumulative distribution functions of some observed values and that of simulation sample values. An auxiliary variable method is used to decompose hybrid parameters into sub-parameters. Then the optimal matching values can be found with genetic algorithm according to the index of difference of joint cumulative distribution functions.

Optimizing Data Structures for Highly Dynamic Content in Collective, Adaptive Systems / Till Köster, Felix Hauptmann, and Adelinde M. Uhrmacher (University of Rostock)

In discrete event simulation of collective, adaptive systems (CAS), it is necessary to store all the entities of the system in some data structure. However, collective adaptive systems, which are characterized by a high fluctuation of entities, pose a challenge for typical data structures. To address this problem we developed the sequential pile container and evaluated its performance based on a set of benchmarks and in comparison to the data structure Set and unordered_set from the C++ template library and a recently developed data structure, i.e., plf::colony. The performance of plf::colony and the sequential pile proved overall superior in these benchmarks, and performed equally well in inserting, copying and iterating over all entities. Sequential pile outperforms plf::colony at deleting elements.

Latency Optimized Execution of Sequential Simulators by Parallel Parameter Optimization / Till Köster, Nicola M. Drüeke, and Adelinde M. Uhrmacher (University of Rostock)

Modern Hardware (even on small desktop systems) provides parallel execution capabilities, which are frequently not utilized by simulators. To increase the effective execution speed of a single simulation run, we will use these parallel hardware resources to execute different simulator configurations of the same

model, explore the performance of different configurations per thread, and propagate superior performing configuration across parallel threads. We show the merit of this method in a small performance study.

Discrete Event Optimization: A Simulation Based Benders Cut Generation Approach / Mengyi Zhang and Andrea Matta (Politecnico di Milano), Arianna Alfieri (Politecnico di Torino), and Giulia Pedrielli (Arizona State University)

Large solution space is one of the main features of simulation–optimization problems. Reducing the car-dinality of the set of alternatives is a key point for increasing the efficiency of simulation–optimization methods. In this work, a new cutting approach is proposed for this purpose. The approach exploits the Benders Decomposition framework that can be effectively applied when the simulation–optimization problems are represented using Discrete Event Optimization models. Benders Decomposition subprob-lems represent the simulation components, hence, cuts can be easily generated observing the values of the variables while a system alternative is simulated, without solving any subproblem. Using this cut genera-tion procedure, the solution space of tandem queueing system optimization problems can be effectively decreased.

Exact Simulation of the Queue-Hawkes Process / Andrew Daw and Jamol Pender (Cornell University)

The Queue-Hawkes process is a generalization of the self-exciting Hawkes process in which the counting process is coupled with an infinite server queue. That is, when a service is completed the process intensity jumps downwards. Thus, the influence an arrival brings to the intensity is ephemeral, as it expires upon the entity's departure. In this poster we provide an exact simulation procedure for this new process via an update of methodology from the traditional Hawkes process literature and discuss the model in general.

Modern Contraception Use in Rural Kenya: Intervention Analysis Through Simulation of Complex Diffusion Processes / Brennan Antone, Noshir Contractor, and Alina Lungeanu (Northwestern University)

Promoting the use of modern contraception (MC) is a critical health issue in rural Kenya. Understanding how MC use is adopted by and diffuses among a given population can aid health works in their attempts to promote use of MC in these populations. In this study, we demonstrate how simulation can be used to understand and intervene in these complex systems of social influence. In order to capture mechanisms behind social influence, we develop an agent based model of the diffusion of health-related beliefs and resulting patterns of MC use in rural villages. Data solicited from all adults (N=1507) in two villages is used to estimate the strength of different social influence mechanisms. After estimating model parameters using Approximate Bayesian Computation, we apply the model towards the selection of an optimal intervention strategy for maximizing contraception use.

Yield, Water Scarcity and Social Attitudes: Insights from an Agent-based Model / Lucia Tamburino (Swedish University of Agricultural Sciences (SLU)), Giuliano Di Baldassarre (Uppsala University), and Giulia Vico (Swedish University of Agricultural Science)

While agricultural yield demand increases, the occurrence of drought during the growing season is becoming more frequent in several regions. Multiple strategies are possible to cope with this problem, such as the choice of high-productive crops and supplemental irrigation. Nevertheless, decision-making is often driven by human perceptions and by the demand for immediate actions, which may result in inadequate or even counter-productive management choices. We addressed this issue by developing a model that simulates a social-agricultural system coupling together environmental dynamics and human responses. We use the model to explore different scenarios, varying climatic and social parameters and analyzing how they can affect the yield productivity in the short and in the medium/long term. Different scenarios are then compared, in order to identify the combinations leading to the most desirable trade-offs, for both the farmers and the environment.

A Multi-Purpose IoT Framework for Smart Built Environments / Reza Tasooji, Archi Dasgupta, and Denis Gracanin (Virginia Tech); Matthew LaGro (OSIsoft); and Kresimir Matkovic (VRVis Research Center)

We describe a framework for storing and analyzing IoT data in smart buildings. The reference implementation of the framework uses MQTT communication

protocol and OSIsoft PI system. What makes this approach different is its capability to leverage a context aware environment. Two case studies were used to test the performance of the proposed framework. The result from the case studies shows that the reference implementation is capable of supporting a real-time data analysis.

Sunday 4:00p.m.-5:30p.m.

PHD COLLOQUIUM / J2

Presentations - II
Jose J. Padilla (Old Dominion University, VMASC)

Agent-based Simulation of the Heating Market using the MCDA Method PROMETHEE / Beatriz Beyer (University of Göttingen)

In Germany, 80 % of the heat demand is still covered by fossil fuels. Decisions for a heating system are cost-intensive long-term investments and influence the sustainability of the market over a long time. In order to obtain deeper insights on the market dynamics for a more sustainable heating market, we developed an agent-based model and applied it to Hanover, a region in northwestern Germany. Different agents in the model represent various heating system owners and their dissimilar decision behavior. The individual decision processes are modeled as multi-criteria decisions using the outranking method PROMETHEE. With the combination of an agent-based simulation and multi-criteria decision processes of heating system owners, the possible effects of different legislations can be observed. Thus, this agent-based simulation model of the heating market could serve as a decision support tool for the industry or policy makers.

Resilience Measurement of the Financial System Considering Recovery Solutions / Mingying Song (The University of Hong Kong)

Resilience is a property of the system, which focuses on the recovery ability of the system after a shock to the system. Financial system plays a key role in our society by performing its functions like risk sharing and information transferring etc. Therefore, resilience is especially important for the financial system. In this study, we present a modified novel simulation model for the risk contagion process of the financial system considering both the network effect and the market liquidity effect. In addition, we put forward several preventive policies as well as some recovery solutions. Based on these recovery solutions, present a measure for resilience in the context of the financial system. A case study considering shocks of different levels is given to illustrate the whole risk contagion and resilience measurement process.

Optimizing the In-house Supplying Routes in the Automotive Industry / Marcelus Fabri Lima (Universitat Pompeu Fabra, SEAT S.A.)

Many works have put their focus on the external logistics and its several applications, such as trucks routing. In contrast, the present research would like to focus on the internal warehouse's activities. Precisely, it aims to cope with the delivery of the components through the workstations inside a car-assembling company. The solutions are computed through a MILP formulation and an ILS, which executes an inter and intra-route neighborhood searches. Next, a Monte Carlo simulation method is embedded, giving rise to the SimILS. Finally, a car-assembling factory's model based on the Discrete-Event Simulation is developed through the PlantSimulation software. Moreover, the routes are studied based on likely stochastic scenarios. Concerning the results achieved so far, it is possible to state that the methodology developed outperformed the current results found in the company, regarding the number of items supplied, the number of waiting materials and the total distance traveled.

Provably Improving the Optimal Computing Budget Allocation Algorithm / Di Wu (Georgia Institute of Technology)

We boost the performance of the Optimal Computing Budget Allocation (OCBA) algorithm, a widely used and studied algorithm for Ranking and Selection (as known as Best Arm Identification) under a fixed budget. The proposed fully sequential algorithms, OCBA+ and OCBAR, are shown to have better performance both theoretically and numerically. Surprisingly, we reveal that in a two-design setting, a constant initial sample size in a family of OCBA-type algorithms (including the original OCBA) only amounts to a sub-exponential or even polynomial convergence rate of the probability of false selection (PFS).

In contrast, our algorithms are guaranteed to converge exponentially fast, as is shown by a finite-sample bound on the PFS.

Unified Packet-level and Fluid-flow Simulation of Large-scale Networks / Matías Bonaventura (University of Buenos Aires, ICC-CONICET)

Mainly two very disparate approaches dominate the Modeling and Simulation (M&S) of data networks. The packet-level approach yields fine-grained results comparable to real data networks, but its complexity makes it unsuitable for the simulation of large high-speed networks. The fluid-flow approach relies on Ordinary Differential Equations approximations for faster simulation, but captures only averaged network behavior. Classically, each approach requires different knowledge and tools making network experts adhere to only one of them. We developed a DEVS-based M&S methodology and tool to define seamlessly fluid-flow and packet-level network topologies under a common formal framework. The approach helps reducing the gap between communities approaching network simulation from the algorithmic and the mathematical perspectives. As a case study, simulation models of the DAta AcQuisition network in the ATLAS experiment at CERN helped in the design, sizing and fine tuning of upgrade projects planned for 2021 and 2027.

The Different Type of Data in Realibility and the Influence in Simulation Techniques / Daniel Gaspar (FEUP-University of Porto)

The world of simulation involve the generation of several independent simulated data sets. These generated data sets must also be completely independent for the different scenarios considered, such as, in the presence of censored data. Designing high-quality simulations that reflect the complex models seen in practice, such as in failures prognostic studies, sometimes is an hard process. In our phd work, we intend to contribute in the way of design and programming algorithms that generate correctly, robust and non-skewed censored data. The methodology and procedure can be a useful tool in the field of simulation of reliability of equipment and compoments. On the other hand, the purpose of this presentation in phd colloquium, is to expose the first part of phd, that develop a methodology and a procedure based in algorithms made in a language, open-source - R a programming language and free software environment for statistical computing.

Methods, Modelers and Fisheries Scientists - Building Bridges / Maria Elena Pierce (Thünen Institute of Baltic Sea Fisheries)

In recent years the stock dynamic of Eastern Baltic Cod (EBC), an ecologically and commercially valuable species, has undergone unexpected changes. This development has prompted the need for simulation models to aid in providing good scientific advice for management strategies. However, a strong scientific connect between the advancing modeling and simulation methods and the domain scientist equipped with intimate knowledge of the Baltic and EBC has not yet been established. Therefore, for any modeling and simulation effort in this domain to have an impact, bridging this gap is vital. Hence, points like choice of best modeling approach and understandable notation such as rule-based or even graphical ones are explored. Managing the complexity of the domain is supported by a component based approach in development together with successive systematic validation. Here progress and future work of reducing the gap for a simulation model on EBC are discussed.

Gradient Based Criteria for Sequential Design / Collin B. Erickson (Northwestern University)

Computer simulation experiments are commonly used as an inexpensive alternative to real-world experiments to form a metamodel that approximates the input-output relationship of the real-world experiment. While a user may want to understand the entire response surface, they may also want to focus on interesting regions of the design space, such as where the gradient is large. In this paper we present an algorithm that adaptively runs a simulation experiment that focuses on finding areas of the response surface with a large gradient while also gathering an understanding of the entire surface. We consider the scenario where small batches of points can be run simultaneously, such as with multi-core processors.

Multi-fidelity Bayesian Optimization with Trace Observations / Saul Toscano-Palmerin (Cornell University)

We propose a new provably-convergent continuous-fidelity Bayesian optimization method where fidelity is controlled by one or more continuous settings, and we have trace observations. For example, we may wish to adjust training data size and number of training iterations, for an optimal accuracy run-time tradeoff. We make two innovations: (1) we fix the widely spread issue that common continuous-fidelity methods always prefer a very low fidelity point no matter how much actual value it can provide, and our fix is theoretically sound; (2) our method is designed in a decision-theoretic manner in light of the fact that we have trace observations. Numerical experiments show that our method outperforms state-of-art algorithms when optimizing synthetic functions, tuning feedforward neural networks on MNIST, tuning convolutional neural networks (CNNs) on CIFAR-10 and SVHN, and in large-scale kernel learning.

Life Cycle Costing in Product Service System Context: A Simulation Approach / Emmanuel Musa (Aston University)

The use of simulation in life cycle cost computation for Product-Service Systems have been limited in scope due to limited data availability at the concept design phase of PSS development. Case studies in the literature are context specific and focus on specific PSS variant. This paper proposes a framework for the life cycle costing of Product-Service Systems based on discrete event simulation methodology using a combination of literature review findings and empirical research. Sensitivity analysis show the influence of varying activity levels on total life costs of different PSS alternatives.

Simulation-driven Embedded Control of Robotic Systems Based on Model Continuity / Ezequiel Pecker Marcosig (FI, UBA and CONICET)

Designing hybrid controllers for cyber-physical systems raises the need to interact with embedded platforms, where robotic applications are a paradigmatic example. This can become a difficult, time consuming and error-prone task for non-specialists as it demands for background on low-level software/hardware interfaces often falling beyond the scope of control designers. We propose a simulation-driven methodology and tool for designing hybrid controllers based on a model continuity approach. The simulation model of a controller evolves transparently from a desktop-based mocking up environment until its final embedded target without the need of intermediate adaptations. We rely on the Discrete EVent Systems Specification (DEVS) framework for robust modeling and real-time simulation of hybrid controllers, and on the Robotic Operating System (ROS), a middleware for flexible abstraction of sensors and actuators. We successfully tested our approach in scenarios where custom-made robots are designed concurrently with their controllers.

Budget Allocation Problem in Simulation Analytics / Xiao Jin (National University of Singapore)

Simulation as a decision supporting tool, in principle is time-consuming and lacks responsiveness. “Time consuming” means that a simulation model often costs a long time to build and validate. Beyond establishment, for each simulation trial, it also takes long to run. On the other hand, the “lacking responsiveness” can be considered in a way that simulation is often used to measure long-term average performance unconditional on any particular system status. In this sense, when an instant decision depending on the current situation is needed, a classical simulation-based optimization tool could do very little. In this research, I shall propose a possible way of exploiting the potential of applying simulation-based optimization in solving the real-time decision problem. Under this new problem setting, a corresponding budget allocation shall be properly derived. A numerical study shall be attached at the end.

Sunday 5:30p.m.-7:00p.m.

JOINT SESSION: POSTER & PHD COLLOQUIUM / CONGRESS FOYER

PhD Colloquium and Poster Session

Monday 8:00a.m.-9:30a.m.

KEYNOTE / CONGRESS HALL

Conference Keynote: Scott F. Breor
Björn Johansson (Chalmers University of Technology)

Assessing Critical Infrastructure Dependencies and Interdependencies / Scott F. Breor, Deputy Assistant Secretary (Acting)
Office of Infrastructure Protection, U.S. Department of Homeland Security

Today's infrastructure is connected to many other infrastructure assets, systems, and networks that it depends on for normal day-to-day operations. These connections, or dependencies, may be geographically limited or span great distances. The many points of infrastructure connections, and their geographic distribution, make the infrastructure environment much more complex. The U.S. Department of Homeland Security (DHS) works to strengthen critical infrastructure security and resilience by generating greater understanding and action across a (largely) voluntary partnership landscape. This is achieved by working with private and public infrastructure stakeholders to resolve infrastructure security and resilience knowledge gaps, inform infrastructure risk management decisions, identify resilience-building opportunities and strategies, and improve information sharing among stakeholders through a collaborative partnership approach. This paper highlights the Department's efforts to present a more comprehensive picture of security and resilience through a "system of systems" approach.

SCOTT BREOR currently serves as the Deputy Assistant Secretary (Acting) for the Office of Infrastructure Protection (IP) within the U.S. Department of Homeland Security's (DHS) National Protection and Programs Directorate (NPPD), where he helps oversee IP's efforts to help secure the nation's critical infrastructure. Previously, Mr. Breor served as the Director of IP's Protective Security Coordination Division (PSCD), where he oversaw a nationwide cadre of critical infrastructure security specialists known as Protective Security Advisors (PSAs). He also led the division's efforts in vulnerability and security gap analysis; support to special events; and training on topics including active shooter preparedness; suspicious activity reporting; and improvised explosive device (IED) awareness and bomb threat management. Mr. Breor has over thirty years of military and senior executive experience in the United States government. Prior to DHS, Mr. Breor was a Naval Aviator and had served as the Senior Policy Advisor for the Chief of Naval Operations on all Homeland Security matters. While assigned to the Office of the Chief of Naval Operations (CNO) he led a division that supported the CNO on key warfare and Homeland Security and Defense policy decisions, which included: interagency coordination, incident management, and Department of Homeland Security/Department of Defense integration. For his work for the CNO and his efforts following the tragic events of September 11, 2001 at the Pentagon, he was awarded the Legion of Merit. As a Naval Aviator he supported operations in Iceland, Greenland, Adriatic, Mediterranean, Azores, and South America. Mr. Breor was a Senior Executive Fellow at the John F. Kennedy School of Government, Harvard University. He received a Masters of Arts in National Security Studies and in Homeland Security and Defense from the Naval Post Graduate School, and received a Masters of Business Administration from the University of Oklahoma. In addition, he earned a Bachelor of Science in Physics from The Citadel.

Monday 10:00a.m.-11:30a.m.

ADVANCED TUTORIALS / R23

Visual Analytics
Adelinde Uhrmacher (University of Rostock)

Visual Analytics for Simulation Ensembles / Kresimir Matkovic (VRVis Research Center), Denis Gracanin (Virginia Tech), and Helwig Hauser (University of Bergen)

We often simulate multiple variations of the same model – a simulation ensemble – to better understand intricate physical phenomena. The analysis of complex simulation ensembles represents a grand challenge which is approached by both computational and interactive, visual methods. We describe how modern visual analytics helps to analyze simulation ensemble data. A clever combination of computational and interactive methods supports the simulation expert

to gain deeper insight into the data and into the physical phenomenon that is represented by the ensemble. An analysis environment that combines interactive visualization and computational analysis provides unique advantages for the exploration and analysis of complex ensemble data. It helps the domain expert to efficiently cope with analysis tasks, in particular when they are only partially defined. In this work, we describe the basics of interactive visual analysis, several approaches to interactive ensemble steering, and means for results quantification and analysis reproducibility.

ANALYSIS METHODOLOGY / CONGRESS HALL

Simulation Input Analysis - I
Henry Lam (Columbia University)

Constructing Simulation Output Intervals under Input Uncertainty via Data Sectioning / Peter W. Glynn (Stanford University) and Henry Lam (Columbia University)

We study the problem of constructing confidence intervals (CIs) for simulation outputs in the presence of input uncertainty, where the constructed CIs capture both the statistical noises from the simulation replications and the input data. We present a simple technique based on sectioning input data that provides exact asymptotic confidence guarantees. Unlike some existing approaches, our technique bypasses the need to consistently estimate variances that could be computationally demanding. It can be flexibly applied to dependent data and to both parametric and nonparametric input models.

MISE-Optimal Grouping of Point-Process Data with a Constant Dispersion Ratio / Huifen Chen (Chung-Yuan University) and Bruce Wayne Schmeiser (Purdue University)

Given a set of point-process event times with constant dispersion ratio, we are interested in estimating the rate function by grouping the event times into count data from equal-width time intervals. We group in order to smooth the resulting piecewise-constant rate function using one of our two existing methods: I-SMOOTH and MNO-PQRS. Using the mean integrated squared error (MISE) for piecewise-constant rate functions, we create two estimators; minimizing the estimated MISE function yields the chosen number of intervals. The MISE function provides insights into the optimal number of intervals as a function of the rate-function shape and expected number of events. Across several examples, our two number-of-intervals estimators perform well and similarly; nevertheless, one dominates in terms of realized MISE value.

Better Input Modeling via Model Averaging / Wendy Xi Jiang and Barry L. Nelson (Northwestern University)

Rather than the standard practice of selecting a single "best-fit" distribution from a candidate set, frequentist model averaging (FMA) forms a mixture distribution that is a weighted average of the candidate distributions with the weights tuned by cross-validation. In previous work we showed theoretically and empirically that FMA in the probability space leads to higher fidelity input distributions. In this paper we show that FMA can also be implemented in the quantile space, leading to fits that emphasize tail behavior. We also describe an R package for FMA that is easy to use and available to download.

AVIATION MODELING AND ANALYSIS / R4

Aircraft Trajectory Modelling and Optimization
Daniel Delahaye (Ecole Nationale de l'Aviation Civile)

Simulation Techniques for Arrival Procedure Design in Continuous Descent Operation / Daichi Toratani, Navinda Kithmal Wickramasinghe, and Hiroko Hirabayashi (Electronic Navigation Research Institute)

Continuous descent operation (CDO) is fuel-saving noise-abating arrival procedures that are used at the Kansai International Airport (KIX). However, CDO can only be performed at night so as not to disturb airflow during heavy daytime traffic. Altitude window has been proposed as a solution to expand the CDO operations. The operational conditions surrounding the arrival route, such as the percentages of aircraft types and the wind conditions, should be adequately considered while designing the altitude window. This study describes the simulation techniques that are used to formulate this design. A fast-time simulation (FTS) is exhibited to calculate the maximum possible range of the

vertical-CDO trajectory. A performance-review method for the altitude window is also depicted using an FTS. Exemplary simulations are conducted using the actual KIX data. Finally, the application of a review method for the altitude window is discussed to develop the total design process.

Sim-Opt in the Loop: Algorithmic Framework for Solving Airport Capacity Problems / Paolo Scala and Miguel Mujica (Amsterdam University of Applied Sciences), Cheng-Lung Wu (University of New South Wales), and Daniel Delahaye (Ecole Nationale de l`Aviation Civile)

The following paper presents an innovative approach for dealing with complex capacity problems in aviation. We introduce a sliding window framework composed by an optimization method with a simulation component. By applying this framework in diverse problems that are dependent on time it is possible to find feasible and close-to-reality solutions in shorter time than the ones that could be achieved by evaluating the problem in the complete time-horizon. The framework can be applied to solve diverse problems in aviation or similar industries. We exemplify the approach with a model of Paris Charles de Gaulle Airport in France.

Coupling of Turnaround and Trajectory Optimization Based on Delay Cost / Judith Rosenow (Technische Universität Dresden) and Michael Schultz (German Aerospace Center)

This study successfully implements flight specific delay costs in an air traffic simulation with a multi-criteria trajectory optimization and exemplifies a coupling of turnaround and trajectory optimization of historical real flights. Therein, delay costs and detour costs for the reduction of contrail formation are individually calculated for each flight and considered in a flight specific multi-criteria trajectory optimization with the air traffic simulation environment TOMATO. Detours in the optimized trajectories are mainly caused by the intent of avoiding contrail formation. With this case study, the historical flight plan could be stretched and departures and arrivals could be more homogeneously distributed during the analyzed three hours while at the same time ecological costs could be saved by 15 per cent. Therewith the promising potential of System Wide Information Management between airports, airlines, air traffic control and customers could once again be shown.

CASE STUDIES / R2

Industry 4.0 - I
José Arnaldo Barra Montevechi (Universidade Federal de Itajubá)

The Role of Simulation Optimization in Process Automation for Discrete Manufacturing Excellence / Jawad ELOMARI (RISE Research Institutions of Sweden AB), Stefan Svensson (ABB AB Corporate Research), and Kerstin Olsson (ABB AB Robotics)

We discuss the application of simulation to estimate a nominal, or target, processing times for work stations on a serial assembly line. The expectation is that having different processing times per sta-tion per product will increase the throughput of the line, compared to having a constant time for all stations. A demonstration case at ABB Robotics in Sweden will be presented. This is a small part in the "Process Automation for Discrete Manufacturing Excellence" project (PADME) involving five manufacturing industry partners and four research organizations, that aim at adapting Industrie 4.0 strategies and existing state-of-the-art technologies into new configurations, serving as a framework that can be used by similar industries.

Application of IoT-Aided Simulation for a Cyber-Physical System / Yifei Tan (Chuo Gakuin University) and Wenhe Yang, Kohtaroh Yoshida, and Soemon Takakuwa (Chuo University)

Internet of Things (IoT) has been attracting much attention due to its economic impacts and high expectations for drastically changing the competitive domain in various industries in the recent year. Digital Twin (DT) has been proposed as a tool for collecting and synchronizing real-world information in real time on the cyber side. However, it is still at the conceptual stage and only a few studies have specifically discussed methods for their construction and implementation. In this study, a framework for constructing DT in an IoT-aided manufacturing environment was proposed. As a case study, we constructed and implemented a DT-oriented simulation model for a sensor-equipped manufacturing system to verify the effectiveness of the framework.

An Architecture for an Autoscaling Cloud-based System for Simulation Experimentation / Simon J. E. Taylor and Anastasia Anagnostou (Brunel University London), Tamas Kiss (University of Westminster), Gary Pattison and Shane Kite (Saker Solutions), and Jozsef Kovacs and Peter Kacsuk (MTA SZTAKI)

More and more simulation applications need high performance computing to deliver the results from experimentation in a timely manner. Cloud computing presents an attractive cost-effective alternative to using a local computing cluster. Normally a user would decide how many cloud computing resources to hire, provision them and then use them for experimentation. However, it may be the case that the user has paid for many instances that were not used. We have proposed the Microservice-based Cloud Application-level Dynamic Orchestrator (MiCADO) to automatically orchestrate and scale cloud computing applications. This article describes the architecture of a version of MiCADO that has been adapted for simulation experimentation.

ENVIRONMENT AND SUSTAINABILITY APPLICATIONS / R11

Environmental Modeling Methodology
Sigridur Sigurdardottir (Arion Bank)

Use of Simulation to Estimate Economic Performances of Two Phenotypes of Sows / Lluís Miquel Plà-Aragonès, Adela Pagès-Bernaus, Lorenzo Fraile-Sauce, and Gloria Abella-Falco (University of Lleida)

A simulation model representing the dynamics of a sow farm is presented in contrast with other modelling approaches. To highlight relevant aspects of the model a real application for comparing two different groups of sows is considered. The main contribution of the model is that it is flexible to represent different sow herd management alternatives through an extensive number of input parameters. This features allow to measure the productivity of sows under different set of parameters and performing virtual experimentation. The example presented here is related to estimate economic performances of two phenotypes of sows from a real experiment. Phenotypes consist of sows resistant to a common disease (porcine reproductive and respiratory syndrome) with respect another group sensitive to the same reproductive disease. Furthermore, the implementation in Extend performs efficiently additional calculations to enlarge the understanding of the productive behavior in each case.

Building Simulation Models of Complex Ecological Systems by Successive Composition and Reusing Simulation Experiments / Maria Elena Pierce and Uwe Krumme (Thünen Institute of Baltic Sea Fisheries) and Adelinde Maria Uhrmacher (Institute of Computer Science University of Rostock)

With an increasing demand to manage biological resources even when the supporting systems undergo significant changes there is great need for ecological models which take into account all system levels relevant to the resource. However, the large ecological models rising to this challenge require expertise from, at times, quite distinct branches of science. Therefore, rather than tasking a single individual or working group to expand models beyond their area of expertise, fusing smaller submodels into large complex ones appears as a natural way forward. We propose to ensure the semantic validity of the fused models by carefully interlinking composition and validation steps exploiting earlier simulation experiments. A simulation model of the cod in the Baltic sea will elucidate the approach as the different aspects of respiration, energy budgets and behavior are fused and validated as a whole after being modeled and validated individually.

Combining Formal Definition of a Simulation Model with Heuristics to Improve Building Sustainability / Pau Fonseca i Casas (Universitat Politècnica de Catalunya) and Antoni Fonseca i Casas (Polyhedra Tech)

Sustainability is related with environmental, social and economic variables. Each one of these areas is, by itself, complex due to the huge number of factors that one must analyze. Because of the combination of the levels with the factors, and the needed replications, an exponential growth in the number of executions appears. In this paper we describe a methodology that helps us to deal with this complexity applying three key concepts, formal representation of simulation models, optimization algorithms and high-performance computing. We present an infrastructure named NECADA that supports the methodology. This approach can be applied to a building refurbishment or to define optimal parameters in new buildings. The specialists work with the conceptual model, and from it with the system; following the method, they will be able to find

optimal scenarios using a selection of build-in heuristics that can be applied for the problem resolution.

GAMING / R5

Rigor in Gaming Simulation
Jayanth Raghothama (KTH Royal Institute of Technology)

Simulation in Facilitation of Operations Management Education / Durk-Jouke van der Zee and Steffan Sloot (University of Groningen)

Traditionally, discrete event simulation is associated with logistic system analysis due to its role as an operations research method. In this article, we consider a multiple case study on the alternative use of simulation for operations management education. When stressing the role of the student or trainee instead of operations—as in operations research—alternative demands on model set up and use arise. Identifying such demands and ways to deal with them extends simulation methodology by showing how to exploit existing simulation knowledge and tools for pedagogic purposes. Our multiple case study evaluates four simulation-based games reflecting operations systems in health care and manufacturing. Respective games target learning activities of a different nature. Outcomes of the evaluation provide insights on modelling requirements, and guidelines and good practices that are supportive in meeting these.

The Future of Contextual Knowledge in Gaming Simulations: A Research Agenda / Bill Roungas (Delft University of Technology), Sebastiaan Meijer (KTH Royal Institute of Technology), and Alexander Verbraeck (Delft University of Technology)

Gaming simulations (games) are increasingly becoming the tool of choice for modeling and understanding the complexity of today's systems. This increased popularity has consequently revealed the weaknesses of games in several areas. These limitations range from inconsistencies on the game design to the unexploited explicit and tacit knowledge that games invoke. This paper focuses on games that do not aim at generalizing the produced knowledge but, instead, at understanding how a system works within a specific context. The first step of the analysis is identifying these limitations based on an extensive literature review. Based on this, different directions that could mitigate or even fully address these limitations are proposed. The paper concludes with a focused research agenda.

Exploring Gaze Behavior to Assess Performance in Digital Game-based Learning Systems / Brian An, Inki Kim, Erfan Pakdamanian, and Donald E. Brown (University of Virginia)

The recent growth of sophisticated digital gaming technologies has spawned an $8.1B industry around using these games for pedagogical purposes. Though Digital Game-Based Learning Systems have been adopted by industries ranging from military to medical applications, these systems continue to rely on traditional measures of explicit interactions to gauge player performance which can be subject to guessing and other factors unrelated to actual performance. This study presents a novel implicit eye-tracking based metric for digital game-based learning environments. The proposed metric introduces a weighted eye-tracking measure of traditional in-game scoring to consider the mental schema of a player's decision making. In order to validate the efficacy of this metric, we conducted an experiment with 25 participants playing a game designed to evaluate Chinese cultural competency and communication. This experiment showed strong correlation between the novel eye-tracking performance metric and traditional measures of in-game performance.

HEALTHCARE APPLICATIONS / R12

Clinical Decision Making
Julie Ivy (North Carolina State University)

Extending a Bayesian Decision-Theoretic Approach to Value-based Sequential Clinical Trial Design / Andres Alban and Stephen E. Chick (INSEAD) and Martin Forster (University of York)

Recent work has illustrated how Bayesian approaches to discrete simulation optimization can be applied to clinical trial design. These approaches balance the expected cost of running the trial with the expected economic benefits of adopting one of the treatments, based on the information which accumulates during the trial. Some work in this space has presented a model of a fully sequential trial,

but with simplifying assumptions; other work has incorporated some special features of pragmatic clinical trials into a one-stage (that is, non-sequential) framework. This paper shows how simulation optimization ideas can be used to model fully sequential sampling for trials which contain these features.

A Simulation Optimization Approach to Optimal Calibrator Level Selection for Clinical Immunoassays / Utkarsh Vardhan and Varun Ramamohan (Indian Institute of Technology Delhi)

Improving bioanalytical procedures (assays) to measure levels of immunologically relevant proteins such as haptoglobin requires minimizing the uncertainty associated with the measurement process. In this work, we consider the question of optimally selecting the concentration levels of calibrators (solutions with known concentrations of haptoglobin) used to calibrate the haptoglobin immunoassay. Specifically, we aim to select calibrator concentration levels such that the net measurement uncertainty at medical decision points is minimized. We accomplish this by constructing a Monte Carlo simulation of the haptoglobin immunoassay that estimates the measurement uncertainty associated with the assay, and then formulating the problem of optimally selecting calibrators to minimize the assay uncertainty at medical decision points as a discrete simulation optimization problem. We demonstrate the application of the NSGS and KN procedures to solve this problem. This work represents a first step towards the utilization of simulation optimization in the optimal design of clinical assays.

What's in a Definition? A Simulation Framework for Modeling Sepsis Interventions using Electronic Health Records / Nisha Nataraj and Julie S. Ivy (North Carolina State University), Jeanne Huddleston (Mayo Clinic), and Ryan Arnold and Muge Capan (Drexel University)

Sepsis, the body's inflammatory response to infection, is a serious complication and leading cause of in-hospital mortality. Timely intervention is both difficult and critical since sepsis can rapidly worsen to organ dysfunction and septic shock. However, the lack of a gold-standard definition renders the lines between these transitions unclear, complicating medical decision-making. Using electronic health records, we build a simulation framework to study the evolution of dynamic physiological and cellular responses to therapeutic interventions in septic patients. Since sepsis trajectories can manifest differently depending on patient characteristics, we incorporate patient heterogeneity through comorbidity, age, race, and gender. Under therapeutic interventions recommended by the Centers for Medicare and Medicaid Services (CMS), we illustrate the framework on patient trajectories using the CMS criteria for sepsis definition. The framework is designed to support the comparison and quantification of the impact of clinical definitions and recommended interventions on the timely identification of sepsis states.

HYBRID SIMULATION / R6

Advanced Topics in Hybrid Simulation
Tillal Eldabi (Brunel University London)

How To Create Empathy and Understanding: Narrative Analytics in Agent-based Modeling / Saikou Diallo, Christopher Lynch, and Krzysztof J. Rechowicz (VMASC) and Gregory Zacharewicz (University of Bordeaux)

In this paper we propose a different approach for interacting and analyzing agent-based models. The approach relies on creating empathy and understanding between physical agents in the physical world (people) and artificial agents in the simulated world (simulated agents). We propose a simulated empathy framework (SEF) in which artificial agents communicate directly with physical agents through verbal channels and social media. We argue that artificial agents should focus on the communication aspects between these two worlds, the ability to tell their story in a compelling way, and to read between the lines of physical agents speech. We present an implementation of the SEF and discuss challenges associated with implementing the framework in an artificial society.

Hybrid User Experience (UX) Modelling in a Heritage Setting / Nada Nasser AlSubhi and David Bell (Brunel University London)

Visitor expectations continually evolve as new forms of technology mediate ever more personalized interactions, not only within the museum, but also virtually around the physical environment. Designing visitor journey experiences that support visitor heterogeneity are complex. Consequently, it is difficult for museum management and collection managers to respond effectively in their design of

heritage experiences. Understanding human behavior at scale is challenging, often explored in other disciplines by simulating generic process models and scenarios. Creating experiences for cultural heritage persona remains a challenge because no clear methodology currently exists. This paper proposes a methodological framework supporting museum and collection managers in their design and simulation of heritage experiences. Clear classification of visitors and journeys is undertaken at the outset. Journey mapping is used as a modeling primitive for both agent and system dynamic modeling.

Modular Simulation of 2nd-Order Energy Preserving Systems / Fernando Barros (University of Coimbra)

Co-simulation requires the ability to represent systems in a modular form, while guaranteeing that simulation algorithms rely exclusively on model external interface. These conditions enable models to be composed without exposing their internal state, a requisite needed for the co-simulation of cyber-physical systems. In this paper we provide a modular representation of geometric integrators, a type of integrator essential to the simulation of 2nd-order energy preserving systems. These integrators offer an alternative to the conventional decomposition of systems into 1st-order Ordinary Differential Equations (ODEs). This latter approach, although commonly used in nowadays M&S software, is not acceptable when long simulation runs are needed. Geometric integrators are represented in the Hybrid Systems Specification (HYFLOW), a modeling formalism to represent hybrid modular dynamic topology systems. We show that HYFLOW enables the composition of geometrical solvers, allowing the co-simulation of complex 2nd-order energy preserving systems.

INTRODUCTORY TUTORIALS / R31

The Basics of Simulation
Omogbai Oleghe (Cranfield University)

The Basics of Simulation / K. Preston White (University of Virginia) and Ricki G. Ingalls (Diamond Head Associates)

Simulation is experimentation with a model. The behavior of the model imitates some salient aspect of the behavior of the system under study and the user experiments with the model to infer this behavior. This general framework has proven a powerful adjunct to learning, problem solving, design, and control. In this tutorial, we focus principally on discrete-event simulation – its underlying concepts, structure, and application.

LOGISTICS, SCM, TRANSPORTATION / R21

Logistics within Cities
Elizabeth R. Rasnick (Georgia Southern University)

Evaluating the Consolidation of Distribution Flows Using a Discrete Event Supply Chain Simulation Tool: Application to a Case Study in Greece / Markus Rabe, Astrid Klueter, and Alexander Wuttke (TU Dortmund University)

Horizontal collaboration (HC) is an innovative strategy aimed at reducing distances traveled through better resource utilization and consolidated product flows. Especially concerning urban freight movements, often summarized in the concept of City Logistics, cooperation between actors on the same supply chain level can be an effective concept to ensure efficiency and sustainability. The aim of this paper is to evaluate possible business opportunities for collaborative freight operation via discrete event simulation. Certain key performance indicators (KPIs) addressing both economic and environmental aspects are used in order to present and evaluate the execution of delivery tours in the city center of Athens and its outskirts. The primary data used for this evaluation are real-life data from Greek third party logistics (3PL) operators and the results show the current impact of two collaboration scenarios involving an Urban Consolidation Center.

Simulation-based Evaluation of Urban Consolidation Centers Considering Urban Access Regulations / Ralf Elbert and Christian Friedrich (Technische Universität Darmstadt)

The negative effects of urban freight transports, such as air quality problems, road congestion, and noise emissions lead in many cities to major difficulties. A widely studied measure to reduce these negative effects are Urban Consolidation Centers (UCCs), which aim to bundle freight flows to reduce the number

of urban freight transports. However, many projects showed that the additional costs of UCCs often made it unattractive for carriers to participate in such schemes. This paper presents an agent-based simulation to assess the impact of urban access regulations on the cost-attractiveness of UCCs for carriers. A case study inspired by the Frankfurt Rhine-Main area is presented to compare deliveries of a group of carriers with and without aUrban Consolidation Center under various urban access scenarios. The simulation shows that regulations increase the cost-attractiveness of UCCs for carriers to varying degrees while increasing the overall traffic volume.

Simulation Assessment of New Generation Navigation Strategies / Lídia Montero and M. Paz Linares (Universitat Politècnica de Catalunya); Josep Casanovas-Garcia (Universitat Politècnica de Catalunya, Barcelona Supercomputing Center); and Gonzalo Recio, Ester Lorente, and Juan Salmerón (Universitat Politècnica de Catalunya)

Probe vehicle (or connected car) data are becoming an important source of real-time travel information for a variety of intelligent transportation system applications. Since traditional sensors have significant installation and maintenance costs, technological companies are interested in traffic data from these alternative detection techniques for computing traffic-aware shortest routes. This paper analyzes and evaluates the use of data provided by probe vehicles in two reactive navigation strategies and how this affects a set of city and driver key performance indicators. The case study adopts a microscopic simulation approach to emulate real-size fleets of probe cars providing positions and speed data. The paper presents and discusses the modeling approach and the obtained results after conducting an experimental design for a Barcelona district scenario. Moreover, a simulation-based framework is introduced for simplifying the analysis of simulation results and easily visualizing origin-destination paths for the proposed driver segments (experts, regular, and tourists).

MASM / R14

Planning in Supply Chains
Georg Laipple (Robert Bosch GmbH)

Augmented Generic Flow Visualization and Aggregation for a Multi-Product Semiconductor Fab / Thomas Winkler and Ralf Sprenger (GLOBALFOUNDRIES Dresden)

Modern semiconductor foundry business involves dozens of different products sharing the same production line. With each of them having distinct flows with potentially different mask layers, process steps and dedicated tools, it is not easy to get a good overview. Furthermore, analyzing simulation results is difficult because the flow of material on the shopfloor inside the simulation is difficult to understand. We describe a dynamic approach of automated, interactive, aggregated flow visualization based on nodes and edges graphs, augmented by current state and simulation data like waiting and upcoming material, tool states and line holds. This allows for a profound analysis of the current state of the production line and the material flow anticipated by the simulation considering all constraints.

Dynamic Price and Lead Time Quotation under Semiconductor Industry Related Challenges / Miray Öner Közen (Technische Universität München) and Hans Ehm (Infineon Technologies AG)

We consider the dynamic price and lead time quotation problem in the practical context of the semiconductor industry. Our model considers an inventory decoupled supply chain and accounts for a limited capacity, stochastic demand and processing times and quote-sensitive customers. We focus on performance evaluation under two decision making strategies. The first is lead time based pricing (LTBP). It follows a sequential approach where the firm decides first on the lead time quote (manufacturing) and then quotes the price under the given lead time (marketing). The second strategy suggests determining the lead time and the price quotes simultaneously. From the practical view-point, it is interesting to first understand the system performance under LTBP and then look for the ways to realize it. Based on our numerical results, we elaborate on the effect of LTBP on the key performance indicators and discuss conditions for close performance to a simultaneous decision strategy.

Production Planning Models with Productivity and Financial Objective Functions in Semiconductor Manufacturing / Sébastien Beraudy, Nabil Absi, and Stéphane Dauzère-Pérès (Mines Saint-Etienne)

In the semiconductor manufacturing literature, production planning models mainly aim at minimizing production, inventory and backlog costs. Solving these models may lead to a poor utilization of the production capacity when there are not enough demands. In this paper, after presenting a first generic linear programming model with fixed lead times when total costs are minimized, a model where productivity is maximized is introduced. Then, a model where the total profit is maximized is proposed, which considers the net present value of the profit through an actualization rate. These models are then compared using a data set from the literature. The numerical results show that, although the model with productivity maximization is performing as expected, the model with profit maximization is more relevant since it also helps to increase productivity. The impact of the actualization rate is analyzed, and also the limitations of the production of some products.

MILITARY APPLICATIONS / R17

Military Keynote: Reiner Huber
Mariusz Balaban (U.S. Army)

Military Modelling and Simulation — A Recollection and Perspective / Reiner K. Huber (Universität der Bundeswehr München)

The roots of today's military modeling and simulation approaches date back to 1938 when OR emerged after a disappointing exercise conducted by the RAF to test the effectiveness of the newly developed radar. It is fair to say that OR support in WWII was decisive in winning the Battle of Britain in 1940 and the Battle of the Atlantic in 1943. After WWII, military OR was re-awakened by NATO when the Cold War began by facilitating the build-up of national military OR institutions to support defense planners and militaries in sustaining a NATO force structure capable of deterring a Soviet aggression. During the decade of cooperation with Russian analysts after the end of the Cold War we found out that, based on the results of war games and battle simulations, Soviet leaders concluded that the risk of not meeting the operational objectives of a successful attack on NATO was too high. Given Putin's revisionist policy, NATO's problem today is how to re-establish deterrence in an ever more complex environment characterized by cyber threats and hybrid warfare. Hopefully, modeling and simulation will again help stabilizing the situation.

REINER K. HUBER is Emeritus Professor at the Universität der Bundeswehr München (UniBwM – University of the German Armed Forces, Munich). He received his academic education from 1954 to 1960 at the Technical University of Munich (TUM) majoring in Mechanical and Aeronautical Engineering and, as a Fulbright Scholar, at the University of Texas majoring in Industrial Engineering. He then served as Technical Officer of the Luftwaffe for three years. In 1964 he joined the OR Group of Germany's newly founded defense support institution IABG as an analyst where he later became head of its Systems Studies Division. As part time research assistant at the TUM he received his Dr,-Ing (PhD) in 1970. In 1975 he was appointed Chair of Applied Systems Science and OR (with emphasis on defense and security issues) in the Department of Computer Science of UniBwM. There, he was dean and member of the Senate from 1981 to 1986. In 2000 he became Emeritus. From 1971 to 1976 he was a member of the NATO-Science Committee's Advisory Panel on OR (APOR) and the Special Program of Systems Science (SPOSS). He was visiting professor at the Naval Postgraduate School in Monterey, California, in 1979 and 1983, and visiting lecturer at the Korean Institute of Defense Analysis in Seoul (1980), the Royal Military College of Science at Shrivenham (1985), and the Military Operations Research and Analysis Institute at the Academy of Military Science in Beijing (1988). He organized and led several international conferences on defense and security analysis and has been a long-time research associate of Vector Research in Ann Arbor, Michigan, and the RAND Corporation in Santa Monica, California, a consultant to NATO and the German Ministry of Defense and he is a Senior Fellow of the Potomac Foundation in Vienna, Virginia. In recognition of his cooperation with Russian analysts after the end of the Cold War he was elected associate member of the Russian Academy of Natural Science in 1995. His recent work is focused on Command and Control for complex endeavors.

MODELING METHODOLOGY / R26

Experiment Design
Andrea D'Ambrogio (University of Roma TorVergata)

Towards An Analytical Framework for Experimental Design in Exploratory Modeling / Enayat A. Moallemi, Sondoss Elsawah, and Michael J. Ryan (The University of New South Wales)

Exploratory modeling—as an approach for modeling under uncertainty—is based on the analysis of computational experiments representing many possible model responses in the face of uncertainty. Experiments are generated based on various design factors, such as the way uncertainties are defined and the techniques by which value sets are sampled from these uncertainties. The choice of the design of experiments can impact on the computational cost of experiments as well as has an effect on the results and the conclusions drawn from those results. Despite this significance, experimental design has not been adequately discussed in the exploratory modeling literature. This article investigates which dimensions and and what methods should be considered for an appropriate design of experiments in exploratory modeling. We conclude that there is a need to develop an analytical framework which can assist modelers to design experiments appropriately and to consider a wide range of model responses.

Gradient Based Criteria for Sequential Design / Collin B. Erickson, Bruce E. Ankenman, and Matthew Plumlee (Northwestern University) and Susan M. Sanchez (Naval Postgraduate School)

Computer simulation experiments are commonly used as an inexpensive alternative to real-world experiments to form a metamodel that approximates the input-output relationship of the real-world experiment. While a user may want to understand the entire response surface, they may also want to focus on interesting regions of the design space, such as where the gradient is large. In this paper we present an algorithm that adaptively runs a simulation experiment that focuses on finding areas of the response surface with a large gradient while also gathering an understanding of the entire surface. We consider the scenario where small batches of points can be run simultaneously, such as with multi-core processors.

Inferential Statistics and Simulation Generated Samples: A Critical Reflection / Marko A. Hofmann and Silja Meyer-Nieberg (Universität der Bundeswehr München) and Tobias Uhlig (University of the Bundeswehr Munich)

A review of recently published papers demonstrates: simulation practitioners apply the standard methods of inferential and descriptive statistics for their reasoning with simulation generated samples without much critical reflection. Yet, simulation-generated samples differ in important aspects from empirical samples, for which the standard statistical methods have been developed. Simulation models do have inherent epistemic and computational limits for replication that do not exist with empirical data sets. Consequently, neither is simulation-based data generation the same as the collection of empirical data nor is the analysis of synthetic data equally beneficial as of empirical data. These differences are much more fundamental for computer simulation than the problems of specific techniques of inferential statistics which have been criticized recently. If simulation generated data is used for testing research hypotheses the core issue is not the method of statistical reasoning but the assurance of what might be called evidential content.

PROJECT MANAGEMENT AND CONSTRUCTION / R24

Advances in Project Scheduling
Christoph Laroque (University of Applied Sciences Zwickau)

Productivity Improvement in Operating Autonomous Plants Subject to Random Breakdowns in Construction / Ming Lu and Monjurul Hasan (University of Alberta)

Realizing continuous operations of autonomous plants subject to finite specialist crew resources for maintenance and repair is vital to achieving productivity and cost-effectiveness in construction operations. This paper presents a practical Monte Carlo simulation-based method to develop autonomous plants operations and maintenance programs. To balance the cost of plant production loss against the cost of hiring maintenance crews, we define a cost function which factors in production output value, resource utilization efficiency and direct cost in con-

nection with both autonomous plants and maintenance crews. An illustration case of planning maintenance crew resources in operating autonomous crushing plants at a quarry site is used to shed light on required input data, simulation processing, and output analysis. The case also has increasing relevance to the construction industry in the near future in terms of planning the operation of a fleet of autonomous equipment in site operations.

Towards Multi-Project Simulation of a Lean Production System for Customized Apartment Buildings / Samuel Korb and Rafael Sacks (Technion - Israel Institute of Technology)

In typical construction projects, general contractors devote significant resources to coordinate the work of multiple subcontractors. Subcontractors and general contractors interests are frequently misaligned, and they strive for local optima. In particular, subcontractors balance the demands of different projects as they search to deploy their resources most productively. The problems are exacerbated where customization, such as tailoring of apartments by clients, disrupts workflow. Separation of standard (structure, public spaces) from customized work (apartment interiors) may drastically improve the production system. Separation represents a fundamental change to industry practice. Evaluating separation requires experimentation on a multi-project scale; agent-based simulation is the only practical research method. Simulations of single project systems showed that Lean interventions improve productivity, cash flow and project duration. Recent work with agent-based simulation with two projects and eight subcontractors has shown that the standard/customized work separation provides additional advantages. Future work will extend the simulations to multiple projects.

Estimating Process Duration and Safeguard Project Planning in a one-of-a-kind Production Environment by the use of Simulation Techniques / Wibke Kusturica and Christoph Laroque (University of Applied Sciences Zwickau) and Deike Gliem, Jana Stolipin, and Sigrid Wenzel (University of Kassel)

Customized engineering and the build-up of unique products are complex tasks, where project management contains lots of uncertainties. Simulation techniques could help to evaluate and achieve improved and more robust plans during project management, but are typically not applied in industry, especially at SMEs (small and medium-sized enterprises). This paper covers some ideas of the joint research project SimCast of the Universities of Kassel and the University of Applied Sciences Zwickau. It aims at the development of a method for duration estimation of a project task during project planning. Based on the researched state-of-the-art, requirements and a planning process are described as well as a draft of the current technical infrastructure of the intended modular prototype. First plug-ins are implemented and already show possible benefits for the project management process. The paper describes possible scenarios for the use of simulation techniques in this setting, based on gained experience.

SIMULATION FOR A NOBLE CAUSE / R22

Humanitarianism - I

David Poza (University of Valladolid)

A Systems Modeling Approach to Analyzing Human Trafficking / Jeffrey Brelsford and Saurabh Parakh (MOSIMTEC)

This paper offers a process for understanding and analyzing the most effective interventions for eliminating human trafficking. The process consists of several methods for gathering, parsing and testing information about the Overseas Filipino Workers (OFW) economic system as it relates to trafficked persons. The methodology is comprised of a series of methods that include interviews, causal loop analysis, data collection, system dynamics simulation model, and scenario simulation runs. The last method, scenario simulation runs, tests the cause and effect relationships between government policies, overseas workers options, hiring companies, and the economy in which they all operate and interact. The importance of this process is that it is robust, repeatable, and efficient in a real-world setting.

Where Are They Headed Next? Modeling Emergent Displaced Camps in the DRC Using Agent-based Models / Erika Frydenlund and Peter Foytik (Old Dominion University), Alain Ouattara (United Nations), and Jose J. Padilla (Old Dominion University)

The paper describes a prototype agent-based model used to predict the spontaneous settlements that can arise among internally displaced forced migrants in the Democratic Republic of the Congo. The internally displaced persons—in the real-world and the model—are constrained by geographic and social forces that dictate their ability to locate and reach organized camps run by humanitarian organizations or instead group with others to establish small temporary settlements. This research is of interest to humanitarian response stakeholders who try to locate self-settlements in order to administer humanitarian assistance and prevent further loss of human life.

How Does Humanitarianism Spread? Modeling the Origins of Citizen Initiatives through Norm Diffusion / Khadijeh Salimi, Erika Frydenlund, and Jose J. Padilla (Old Dominion University) and Hanne Haaland and Hege Wallevik (University of Agder)

This paper describes a prototype agent-based model used to explain why and how a norm of humanitarianism diffuses through a population. The model is constructed on norm diffusion theories as a foundation for developing explaining the emergence of Citizen Initiatives in a humanitarian and development context. We assume that in the model, some agents are already norm adopters (advocates), some have a humanitarian potential that can be activated with persuasion, while others will never adopt the norm of humanitarianism under any condition. In this model, we try to determine whether parameters such as agents' values, thresholds for accepting alternative values, values degradation, and peer-pressure affect agents' decision to become humanitarian activists.

SIMULATION OPTIMIZATION / J2

Ranking and Selection in SO
Yijie Peng (Peking University)

A Review of Static and Dynamic Optimization for Ranking and Selection / Yijie Peng (Peking University), Chun-Hung Chen (George Mason University), Edwin Chong (Colorado State University), and Michael Fu (University of Maryland)

We review static and dynamic optimization formulations for simulation allocation and selection procedures and revisit several sampling approaches under a single umbrella. We conduct some new simulation experiments to illustrate where the static optimization approach may be inadequate to capture the dynamic sampling decisions and show how many existing sampling procedures ignore certain important considerations.

Provably Improving the Optimal Computing Budget Allocation Algorithm / Di Wu and Enlu Zhou (Georgia Institute of Technology)

We boost the performance of the Optimal Computing Budget Allocation (OCBA) algorithm, a widely used and studied algorithm for Ranking and Selection (as known as Best Arm Identification) under a fixed budget. The proposed fully sequential algorithms, OCBA+ and OCBAR, are shown to have better performance both theoretically and numerically. Surprisingly, we reveal that in a two-design setting, a constant initial sample size in a family of OCBA-type algorithms (including the original OCBA) only amounts to a sub-exponential or even polynomial convergence rate of the probability of false selection (PFS). In contrast, our algorithms are guaranteed to converge exponentially fast, as is shown by a finite-sample bound on the PFS.

Data-Driven Ranking and Selection: High-Dimensional Covariates and General Dependence / Zeyu Zheng (University of California, Berkeley); Xiaocheng Li (Stanford University); and Xiaowei Zhang (Hong Kong University of Science and Technology)

This paper considers the problem of ranking and selection with covariates and aims to identify a decision rule that stipulates the best alternative as a function of the observable covariates. We propose a general data-driven framework to accommodate (i) high-dimensional covariates and (ii) general (nonlinear) dependence between the mean performance of an alternative and the covariates. For both scenarios, we design new selection procedures and provide certain statistical guarantees, by leveraging the data-intensive environment and vari-

ous statistical learning tools. The performances of our procedures are exhibited through simulation experiments.

SIMULATION STANDARDS AND REPRODUCIBILITY / R15

Issues in Simulation Standards

Sanja Lazarova-Molnar (University of Southern Denmark)

The Elusiveness of Simulation Interoperability –What is different from other Interoperability Domains? / Andreas Tolk (The MITRE Corporation)

Simulation interoperability is a recurring theme in simulation conferences and workshops for more than 20 years. With the IEEE Standards 1278 and 1516, two simulation interoperability standards were introduced, and both were adapted and implemented by the community. Nonetheless, the simulation community is still struggling with interoperability challenges that are not solved. Why is this the case? This paper gives an overview of the current approaches to simulation interoperability, including the standardized approaches as well as contributions of simulation formalism. It then addresses the mathematical foundations of simulation interoperability, including model theory. As a result, the need for the consistency in the representation of truth in all participating simulation systems emerges as the concept that needs to be addressed by interoperability solutions.

Challenges of Data Acquisition for Simulation Models of Production Systems in Need of Standards / Maja Bärring (Chalmers Univerisity of Technology), Erik Flores-Garcia (Mälardalen University), Björn Johansson (Chalmers Univerisity of Technology), Jessica Bruch (Mälardalen University), and Mats Wahlström (RUAG Space AB)

In this paper, we analyze the challenges in data acquisition for simulation models of production systems based on two cases from the robotics and aerospace industries. Unlike prior research, we focus not only on the challenges of data acquisition but also on how these challenges affect decisions in production systems. We examine this linkage using the concepts of strategic objectives, decision areas, and internal fit from operations management literature. Empirical findings show that for data acquisition to lead to improved production system performance it is necessary to develop standards. Standards should consider ownership of data by different functions within a manufacturing company, alignment of data to performance measurements, and the connection between data, information, and production decisions. Using these concepts, this paper proposes a set of guidelines that facilitate the standardization of data acquisition for simulation models in production systems. We conclude by discussing the managerial implications of our findings.

Enabling Control System and Cloud-based Simulation Service Interoperability / Albert Jones, Guodong Shao, and Frank Riddick (National Institute of Standards and Technology)

The latest innovations in Information and Communication Technologies (ICT) will change manufacturing and simulation forever. One of those changes involves the use of simulation-based cloud services and the integration of those services with operational problems on the shop floor. In this paper, we focus on the control problems, which we represent as a multilayer process graph. The nodes in this graph are control functions, which are cognitive in nature and can be executed by different agents. The links in the graph are the information objects needed by each agent to execute its assigned functions. We also describe a generic sets of control functions and the roles that simulation can play in executing those functions. This means that simulation is now part of an integrated process and can no longer be thought of as a stand-alone technology. In this paper, we discuss issues and propose approaches to addressing that integration.

VENDOR TUTORIALS / R25

FlexSim / SAS Simulation

Introduction to Simulation with FlexSim / Bill Nordgren (FlexSim Software Products, Inc.)

Join FlexSim CEO Bill Nordgren in a hands-on presentation where you'll learn how to build simulation models using FlexSim simulation software. FlexSim combines powerful statistical analysis with 3D visualization, allowing you to test "what if" scenarios in a risk-free virtual environment. You'll be introduced to FlexSim's powerful standard object library, which includes a variety of pre-built,

customizable objects that you can drag and drop quickly and accurately imitate a real-world system—plus our vast array of logic-building and application-specific tools for any modeling situation. Stop by and see how FlexSim can help you get the most of your process improvement initiatives.

Looking Beyond the Model with SAS Simulation Studio: Data Input, Collection, and Analysis / Edward P. Hughes and Anup C. Mokashi (SAS)

Discrete-event simulation is regularly intertwined with many other forms of analytics. Source data often must be repaired or processed before being used to characterize variation in a simulation model. Collection of simulated data needs to coordinate with and support the evaluation of performance metrics. Or you might need to integrate other analytics into a simulation model to capture specific complexities in a modeled system. SAS Simulation Studio provides an interactive, graphical environment for building, running, and analyzing discrete-event simulation models, and is an integral part of the SAS analytic platform. We illustrate how SAS Simulation Studio helps you tackle each of these challenges. You have full control over the use of input data and the creation of simulated data. Strong experimental design capabilities mean you can simulate for all needed scenarios. Additionally, you can embed any SAS analytic program—optimization, data mining, or otherwise—directly into the execution of your simulation model.

Monday 11:30a.m.-12:15p.m.

WORLD CAFÉ / CONGRESS FOYER

World Café - I
Margaret Loper (Georgia Tech Research Institute)

The goal of World Café is to create new points of view through dialogue and discussion. Participants will discuss topics at different tables over lunch. Each table will have a host, who will introduce the topic and facilitate the discussion. Ideas, questions, and concerns that are generated will be captured, enabling participants to pool their ideas and examine issues from various angles.

Monday 12:20p.m.-1:20p.m.

TITANS OF SIMULATION / CONGRESS HALL

Titan Talk: Peter Frazier
Sanjay Jain (The George Washington University)

Bridging the Gap from Academic Research to Industry Impact / Peter I. Frazier (Cornell University)

Academic methodological research is often done with the hope of creating mathematical methods that will be used in practice. At the same time, there is a significant gap between publishing papers and having the methods described actually be used in industry. In this talk, we offer advice for bridging this gap. We discuss challenges arising from a difference in focus between academic and industry research, and also an incomplete awareness within academia of the full context in which methods are deployed in industry. We then discuss strategies for overcoming these challenges, describing them using examples from the presenter's experiences as a data science manager at Uber working on Uber's carpooling product, UberPOOL, and as an academic developing Bayesian optimization algorithms for use at Yelp and the Bayesian optimization startup company SigOpt. This talk is aimed at academics who want their research to be used in industry, soon-to-graduate PhD students who are making a leap into an industry career, and practitioners interested in exploring ways to be more effective.

PETER I. FRAZIER is an Associate Professor in the School of Operations Research and Information Engineering at Cornell University, and a Staff Data Scientist at Uber. He received a Ph.D. in Operations Research and Financial Engineering from Princeton University in 2009. His academic research is in optimal learning, including Bayesian optimization and optimization via simulation, focusing on applications in e-commerce, materials design, and transportation. At Uber, he managed data science for UberPOOL, Uber's carpooling product, from 2015 to 2016 while on sabbatical leave from Cornell, and now advises

a number of driver-focused data science teams. He is an associate editor for Operations Research, ACM TOMACS, and IISE Transactions, and is the recipient of an AFOSR Young Investigator Award and an NSF CAREER Award. His email address is pf98@cornell.edu.

Monday 1:30p.m.-3:00p.m.

ADVANCED TUTORIALS / R23

Aggregation Methods for Complex Models
Helena Szczerbicka (Leibniz University of Hannover)

Speeding Up Stochastic and Deterministic Simulation by Aggregation: An Advanced Tutorial / Mirco Tribastone (IMT School for Advanced Studies Lucca) and Andrea Vandin (Technical University of Denmark)

Dynamical models of systems across many branches of science and engineering can be mathematically represented in terms of stochastic processes such as Markov chains, or deterministically through a system of difference or differential equations. Unfortunately, in all but special cases these models do not enjoy analytical solutions, hence one is left with computer-based approaches by means of stochastic simulators and numerical solvers. As a consequence, the computational cost increases with the dimensionality of the model under consideration, hindering our capability of dealing with complex large-scale models arising from accurate mechanistic descriptions of real-world systems. This paper offers an advanced tutorial on an array of recently developed algorithms that seek to tame the complexity of these models by aggregating their constituting systems of equations, leading to lower-dimensional systems that preserve the original dynamics in some appropriate, formal sense.

JOINT SESSION: AGENT-BASED SIMULATION & GAMING / R5

Agent Based Gaming
Sebastiaan Meijer (KTH Royal Institute of Technology)

History-based Single Belief State Generation for Partially Observable Real-Time Strategy Games / Weilong Yang (National University of Defense Technology), Lin Sun (National Defense University), and Yong Peng and Quanjun Yin (National University of Defense Technology)

Researches of AI planning in Real-Time Strategy (RTS) games have been widely applied to human behavior modeling and war simulation. Due to the fog-of-war, planning in RTS games need to be implemented under partially observable environment, which poses a big challenge for researchers. This paper focuses on extending Hierarchical Task Network (HTN) Planning in partially observable environment, and proposes a partially observable adversarial hierarchical task network planning with repairing algorithm named PO-AHTNR. By adding sensing action into HTN domain knowledge, a reconnaissance strategy and a history-based single belief state generation method are presented to obtain the best action. In order to verify the proposed algorithm, an empirical study based on μRTS game is carried out, and the performance of modified algorithm is compared to that of AHTNR and other state-of-the-art search algorithms developed for RTS games.

Pipelines and Their Compositions for Modeling and Analysis of Controlled Online Networked Social Science Experiments / Vanessa Ines Cedeno-Mieles (Virginia Tech; Escuela Superior Politecnica del Litoral, ESPOL); Yihui Ren, Zhihao Hu, and Xinwei Deng (Virginia Tech); Noshir Contractor (Northwestern University); Saliya Ekanayake (Virginia Tech); Joshua M. Epstein (New York University); Brian J. Goode, Chris J. Kuhlman, and Dustin Machi (Virginia Tech); Michael W. Macy (Cornell University); and Madhav V. Marathe, Henning H. Mortveit, Naren Ramakrishnan, Parang Saraf, and Nathan Self (Virginia Tech)

There has been significant growth in online social science experiments in order to understand behavior at-scale, with finer-grained data collection. Considerable work is required to perform data analytics for custom experiments. We also seek to perform repeated networked experiments and modeling in an iterative loop. In this work, we design and build four composable and extensible automated software pipelines for (1) data analytics; (2) model property inference; (3) model/simulation; and (4) results analysis and comparisons between experimental data and model predictions. To reason about experiments and models, we design a formal data model. Our data model is for scenarios where subjects can repeat

actions (from a set) any number of times over the game duration. Because the types of interactions and action sets are flexible, this class of experiments is large. Two case studies, on collective identity and complex contagion, illustrate use of the system.

Myopia in Dynamic Spatial Games / Shane Auerbach (Lyft Inc.) and Rebekah Dix (University of Wisconsin)

We design an experiment to evaluate behavior in a dynamic spatial game representing the incentives faced by drivers on a ridesharing platform while waiting to be matched with a rider. The design is unique in that it allows us to observe not only participants' choices, but also the considerations that went into those choices. The results of the experiment show that a large majority of player choices are consistent with myopic best responding - a myopic best response maximizes a player's flow payoff at the time of the decision but ignores strategic considerations regarding the future choices of opponents. Given this finding, we develop agent-based models of spatial competition built upon myopic agents. Myopic behavior in our model results in quite efficient outcomes, suggesting that ridesharing platforms may benefit from sharing with drivers the locations of other nearby drivers to allow them to compete spatially.

ANALYSIS METHODOLOGY / CONGRESS HALL

Simulation Input Analysis - II
Enlu Zhou (Georgia Institute of Technology)

Online Quantification of Input Uncertainty for Parametric Models / Enlu Zhou and Tianyi Liu (Georgia Tech)

It has become increasingly important to assimilate "online data" that arrive sequentially in time for real-time decision. Input uncertainty quantification in stochastic simulation has been developed extensively for batch data that are available all at once, but little has been studied for online data. In this paper, we propose a computationally efficient method to incorporate online data in real time for input uncertainty quantification of parametric models. We show finite-sample bounds and asymptotic convergence for the proposed method, and demonstrate its performance on a simple numerical example.

Uncertainty Quantification in Simulation Models: A Proposed Framework and Application Through Case Study / Anna Paula Galvão Scheidegger and Amarnath Banerjee (Texas A&M University) and Tábata Fernandes Pereira (Universidade Federal de Itajubá)

Despite the great advances in modeling and simulation techniques, modelers and researchers acknowledge that models are simplified representations of reality and, hence, are subject to uncertainty and errors. Although models are inevitably uncertain, they can still be a valuable decision-support tool if the users are informed about the uncertainty in the results. The importance of model uncertainty identification and quantification becomes clear in this context, but there are numerous challenges that remain. In this work, an uncertainty analysis framework is proposed for simulation models. This framework comprises of the steps that must be performed to analyze the uncertainty in simulation models. Next, an application of the framework is discussed where entropy is used as a possible measure of input-uncertainty. By using this framework, stakeholders can be better advised regarding the applicability and uncertainty of the simulation model, which will lead to an appropriate adjustment of expectations on the model results.

Subsampling Variance For Input Uncertainty Quantification / Henry Lam and Huajie Qian (Columbia University)

In stochastic simulation, input uncertainty refers to the output variability arising from the statistical noise in specifying the input models. This uncertainty can be measured by a variance contribution in the output, which is estimated commonly via the bootstrap. However, due to the convolution of the simulation noise and the input noise, the computation effort required in the existing bootstrap schemes are typically substantial. This paper investigates a subsampling framework as a computation saver. We demonstrate the strengths of our subsampled bootstrap in terms of theoretical computation requirements, and substantiate them with numerical illustrations.

AVIATION MODELING AND ANALYSIS / R4

Capacity Analysis and Optimization
Mihaela Mitici (TU Delft)

Capacity Analysis for Aircrew Training Schools - Estimating Optimal Manpower Flows Under Time Varying Policy and Resource Constraints / Pooia Lalbakhsh (RMIT University), Vicky Mak-Hau (Deakin University), René Séguin (Defence Research Development Canada), and Vivian Nguyen and Ana Novak (Defence Science and Technology Group)

Capacity analysis for systems with time varying constraints is still an open problem in Operations Research due to the non-stationarity of the problem domain. This is particularly true for Defence manpower supply which is subject to frequent temporal policy and resource changes. As such, the problem cannot be completely covered with a single overriding simulation or optimisation solution, but, rather, better described using piecewise interplay between simulation and optimisation. This paper describes such an approach for a flexible, interactive capacity analysis simulator with an embedded integer linear programming (ILP) optimiser.

Potential Cost-Benefit Analysis for the Assessment of Air Corridor Installation into Japanese Airspace / Noboru Takeichi, Satoshi Yamamoto, and Yasuo Morooka (Tokyo Metropolitan University) and Akinori Harada (Kochi University of Technology)

The air corridor is an airspace concept to optimize operational efficiency of flights inside it. However, it inevitably becomes a huge obstacle for aircraft flying outside it. In this study, the cost-benefit analysis is performed in order to clarify the feasibility and the conditions at which the air corridor installation becomes beneficial. The increases of the operational cost of the flights outside the air corridor is analyzed through the comparison between the actual trajectories and numerical simulations of the trajectories to avoid the air corridor. The reduction of the operational cost by flying along the optimum trajectories inside the air corridor is also analyzed through comparison with actual trajectories. It has been clarified that even a small number of flights operated inside the air corridor achieves total operational cost reduction. It is further concluded that the air corridor should be installed as early as onboard self-separation capability becomes available.

Life-Cycle Engine Fleet Simulation for Spare Part Inventory Management with Advanced Condition Information / Ana Muriel (University of Massachusetts Amherst); Michael Prokle (Philips Research North America, Northeastern University); and Robert N. Tomastik (Pratt & Whitney)

The cost efficient management of spare parts for low-volume high-tech equipment is inherently difficult. In this on-going study, we seek to improve the OEM's spare parts inventory management by incorporating the condition information from a large number of distributed working units in the field. For that purpose, the condition information relayed by sensors is put in context with usage parameters, preventive replacement policies, customer plans, and current economic indicators to create an aggregate forecast and inventory ordering policy. This requires a synthesis of the state of the art knowledge from multiple research streams. In this paper, we outline a simulation environment of the maintenance management of a jet engine program over its life cycle, and provide preliminary results highlighting several modules for future research to improve the performance of spare part inventory policies and assess the value of health monitoring.

CASE STUDIES / R2

Industry 4.0 - II
Stefan Bengtsson (ÅF)

Releasing the Flexibility: a Case Study of Simulation Modeling for Flexible Manufacturing System / Boyang Song, Windo Hutabarat, and Ashutosh Tiwari (University of Sheffield) and Shane Enticott (Cosworth Ltd.)

This paper describes how simulation can be an effective tool for investigating the dynamic behavior of complex manufacturing systems. Flexible Manufacturing System (FMS) aims to provide optimal machine flexibility, process flexibility, and product flexibility. However, releasing flexibility in FMS is challenging due to the necessary complexity of coordinating all subsystems while simul-

taneously scheduling multiple product families. In this paper, an automotive industry case study is outlined, and a Discrete Event Simulation (DES) model has been developed. The model sufficiently represents all primary subsystems to capture their dynamic interactions, providing a bird's eye view of all critical activities within an FMS. A series of manufacturing problems and their corresponding hypothetical solutions have been explored and evaluated in a number of simulation scenarios. The results demonstrate that releasing FMS flexibility can result in significant performance improvements whilst also removing barriers (such as operation sequencing or line balancing) associated with dedicated manufacturing systems.

Short-Term Forecasting in Open Pit Mining Using Simulation Modeling / Brock Reynolds and Laurens Koelewijn (The Simulation Group)

Simulation modelling has long been used to support operations strategy decisions in the mining industry. Recently, the commodity cycle and push for lower costs has driven efforts to improve operations efficiency. The use of simulation has typically been challenging in the operational time horizon due to the difficulty of initializing the system state and the sensitivity of the results to initial conditions. However, a recent explosion in data availability has made it feasible to know, in real time, the location of each piece of equipment in the fleet, what it is carrying and where it is going. This makes it possible to simulate and predict production performance within a shift and to allow testing of what-if scenarios to improve operations efficiency. In this case study we describe the approach taken, the application of simulation for short-term forecasting and the challenges faced implementing this for a global mining company.

Using Point Cloud Data in Simulation Models / Liang Gong, Henrik Söderlund, Leonard Bogojevic, Jonatan Berglund, Daniel Nåfors, and Björn Johansson (Chalmers University of Technology)

Simulation models can benefit from the latest 3D laser scanning technology, as showed in the current projects SUMMIT and ECOPRODIGI. Using point cloud data of the physical environment generated from 3D laser scanning, we can emulate a spot welding process as-is in an immersive virtual reality environment that looks like the real facility. Point cloud data can also be used to evaluate volumetric filling of cargo space, as visualized in this demo using a 3D laser scanned RoRo ferry. The point cloud data can also help generate accurate models of the hulls for larger ships that can be used to simulate the flow of water, allowing engineers to predict the effect of changes to the hull and traveling conditions to reduce emissions and fuel consumption.

ENVIRONMENT AND SUSTAINABILITY APPLICATIONS / R11

Urban Ecology

Jonathan M. Gilligan (Vanderbilt University)

Simulation to Predict Cyclists' Exposure to Air Pollution along Bikeways / Daniela Azumendi, Juan José Diaz Baquero, Juan Felipe Franco, and Ivan Mura (Universidad de los Andes)

Cyclists riding in polluted urban environments may be exposed to unhealthy conditions. Therefore, the design process of bikeway routes should take into account the exposure of cyclists to air pollutants. Riding a bicycle is a common way to commute in Bogotà, a highly polluted city. Quinto Centenario is a 25-km bikeway, to be built in the coming years. This study aims at producing estimates for Quinto Centenario users exposure to particulate matter. We simulated the movement of bikers along the planned route, and we used air quality data collected by a monitoring network to estimate the pollution concentration bikers will be exposed to. Bikeway traffic estimates were obtained from official city surveys, which we analyzed to determine origin/destination matrices for bike trips and trip duration distributions. The output of simulation is captured by a spreadsheet that computes bikers' exposure for any path along the bikeway.

Power Storage Modeling for Renewable Energy Systems / John M. Betts and Heshan Kumarage (Monash University)

Renewable energy production is increasing, and the cost of power storage is decreasing, enabling users to exercise control over their power consumption from the electricity grid. To achieve partial or complete energy independence, consumers need to be able to calculate the energy storage required to cover periods when renewable power is not being produced. To address this need, a model is introduced which determines energy storage characteristics from

a single simulation of an energy production system. From this model, the optimal storage size necessary for a required level of grid-independence can be calculated quickly, to a high degree of accuracy. By using existing data, no user estimation of demand parameters is required, making this model accessible to non-specialists. The optimal battery size for a domestic photovoltaic - battery system under varying demand and production scenarios is analysed and the accuracy and computational performance of the model assessed.

Dynamic Behavioural Modeling, Simulation and Analysis of Household Water Consumption in an Urban Area: A Hybrid Approach / Muhammad Saad Qaisar Alvi and Imran Mahmood (Center for Research in Modeling & Simulation (CRIMSON), National University of Sciences & Technology); Fahad Javed and Asad Waqar Malik (Center for Research in Modeling & Simulation (CRIMSON), National University of Sciences and Technology); and Hessam Sarjoughian (Arizona Center for Integrative Modeling & Simulation (ACIMS), Arizona State University)

Pakistan is rapidly becoming a water stressed country, thus affecting people's well-being. Authorities are faced with making drastic water conservation policies toward achieving effective management of available water resources and efficient water supply delivery coupled with responsible demand side management. Due to the lack of modern water metering in Pakistan, water consumption is not being accurately monitored. To achieve this goal, we propose a hybrid modeling and simulation framework, consisting of: (i) Agent-based Modeling (ABM) paradigm that deals with the behavior and characteristics of individuals and (ii) System Dynamics(SD) paradigm that accounts for water flow dynamics. Our approach provides dual-resolution expressiveness suitable for replicating real-world urban infrastructure scenarios. The key objective of the research is to assist authorities to understand and forecast short-term and long-term water consumption through examining varying patterns of water consumption in different climates and thus improving demand side water usage dynamically subject to water supply availability.

HEALTHCARE APPLICATIONS / R12

Emergency Departments

Vincent Augusto (Ecole Nationale Superieure des Mines de Saint Etienne)

A Modelling and Simulation Framework for Intelligent Control of Emergency Units in the Case of Major Crisis / Vincent Augusto (Mines Saint-Etienne) and Martin Murgier and Alain Viallon (CHU Saint-Etienne)

A modelling and simulation framework for the performance evaluation of emergency units and intelligent control in the case of major crisis is proposed in this paper. Taking into account new challenges related to the optimization of the patient care pathway in the emergency unit in the context of major crises, we propose a flexible tool that can be used by health-care practitioners as a decision aid in various situations under the shape of a digital twin of the emergency unit. The modelling framework is based a modular model with specific representation of care pathways and resources activities. Various arrival processes are modelled in order to comply with the periodic variations observed in data history as well as exceptional massive arrivals that may be related to major crisis. A practical experiment is provided in order to determine the best available leverages to optimize the operations of the system.

Evaluation of Interventions for Psychiatric Care: A Simulation Study of the Effect on Emergency Departments / Thomas Roh (HDR, Inc.); Valerie Quinones-Avila (University of Puerto Rico); and Ronna L. Campbell, Gabrielle Melin, and Kalyan S. Pasupathy (Mayo Clinic)

Hospital-wide strategies for reducing mental health (MH) boarding in the emergency departments (ED) have focused on improving the onsite patient flow and resource management. A gap in literature is still residing on the lack of consideration for the MH transition process from the ED into external community and hospital inpatient psychiatric settings, as well as the external bed capacity limitations. Discrete event simulation was used to understand the mental health patient flow within the ED and to inpatient settings. It provided a forecast of system changes when three scenarios were tested to determine the percentage increase in beds necessary to reduce MH ED boarding time. These alternative approaches illustrate the applicability of the model as a decision support tool for evaluating solutions to MH ED boarding.

Improving Quality of Care in a Multidisciplinary Emergency Department by the Use of Simulation Optimization: Preliminary Results / Li Zhang (University Hospital of Giessen and Marburg GmbH); Ferdinand Baer and Boris Amberg (FZI Research Center for Information Technology); Stefan Nickel (Institute of Operations Research (IOR), Karlsruhe Institute of Technology (KIT); FZI Research Center for Information Technology); and Clemens Kill and Andreas Jerrentrup (University Hospital of Giessen and Marburg GmbH)

A major challenge of an emergency department (ED) is managing the growing patient volume without diminishing quality of care nor increasing costs. Therefore, this case study aims at minimizing the average patient's length-of-stay (LOS) subject to a given staffing budget. It is based on data of a multidisciplinary ED in Germany with an annual volume of 50,000 patients. We analyze the impact of process modifications, staff pooling, and optimized staffing levels on the LOS. In order to optimize staffing levels, we combine optimization models with discrete-event simulation. The simulation model is built on treatment processes of different medical specialties that were mapped by time-motion studies. Results show that avoiding boarding time and pooling of nurses originally assigned to internal medicine or neurology are particularly promising. These lead to improvements of 15% and 14% in avg. LOS, respectively. Optimizing staff allocation results in reductions of up to 9% in avg. LOS.

HYBRID SIMULATION / R6

Hybrid Simulation General Applications
Masoud Fakhimi (University of Surrey)

A Co-Simulation Technique for Efficient Particle Tracking Using Hybrid Numerical Methods With Application in High Energy Physics / Lucio Santi and Rodrigo Castro (Universidad de Buenos Aires, ICC-CONICET)

Particle tracking in physical systems is a well known simulation challenge in many domains. In particular, High Energy Physics (HEP) demand efficient simulations of charged particles moving throughout complex detector geometries in a magnetic field. Quantized State Systems (QSS) is a modern family of hybrid numerical methods that provides attractive performance features for these problems. Its state-of-the-art implementation is the general-purpose QSS Solver toolkit. Meanwhile, Geant4 is the most widely used platform for computational particle physics, embedding vast amounts of physics domain knowledge. Yet, Geant4 relies rigidly on classic discrete time numerical methods. In this work we present a robust co-simulation technique to apply QSS in the simulation of HEP experiments, thus leveraging the best of both toolkits. We obtained speedups of up to three times in synthetic, yet representative scenarios, and a competitive performance in a difficult benchmark modeled after the Compact Muon Solenoid (CMS) particle detector at CERN.

Multi-Objective Decision Making in Multi-Period Acquisition Planning Under Deep Uncertainty / Enayat A. Moallemi, Sondoss Elsawah, Hasan H. Turan, and Michael J. Ryan (The University of New South Wales)

Acquisition planning involves decisions to be made regarding the number of assets to be acquired initially and the type and timing of replacement and upgrade actions to maintain performance measures efficiently. Acquisition planning is challenging for high-valued assets because of considerable uncertainties in their long-term life cycle. This article proposes an approach to determine which acquisition strategy—i.e. what initial number of assets, what number of new acquisitions, and in what time throughout a long-term planning period—can robustly fulfil multiple performance objectives in the face of plausible future scenarios. The article incorporates robust optimization for the treatment of uncertainty inside the simulation multi-objective optimization process where the robustness of different acquisition strategies in future scenarios is analyzed by running many simulations. A fleet management system is used as an illustrative hypothetical example. The results show an adaptation map of robust acquisition strategies over the life cycle of the fleet.

An Improved Simulation of Hybrid Biological Models with Many Stochastic Events and Quasi-Disjoint Subnets / Mostafa Herajy (Port Said University) and Monika Heiner (Brandenburg University of Technology)

Hybrid simulation, combining exact and approximate algorithms, provides an alternative to a completely stochastic simulation. However, one challenge for the efficient implementation of hybrid simulations is the additional overhead due to frequent switches between the two regimes. The amount of additional

overhead considerably increases with the number of discrete events in the stochastic regime. However, reactions that take place rather frequently cannot completely be avoided due to the accuracy requirements. In this paper, we present an improved hybrid simulation method which takes advantage of the Hybrid Rejection-based Stochastic Simulation Algorithm (HRSSA), a variant of the hybrid simulation approach. To reduce the overhead on account of the switches from the stochastic to the deterministic regime, we analyse and record the dependencies of reactions as well as species between the stochastic and deterministic subnetworks. Comparing our technique with existing ones shows a clear improvement in terms of runtime, while preserving accuracy.

INTRODUCTORY TUTORIALS / R31

DEVS Modeling and Simulation
Nura Tijjani Abubakar (Brunel University London)

Discrete Event System Specification Modeling and Simulation / Yentl Van Tendeloo (University of Antwerp) and Hans Vangheluwe (University of Antwerp and Flanders Make vzw)

Discrete Event System Specification (DEVS) is a popular formalism for modeling complex dynamic systems using a discrete-event abstraction. At this abstraction level, a timed sequence of pertinent "events" input to a system (or internal timeouts) cause instantaneous changes to the state of the system. Main advantages of DEVS are its rigorous formal definition and its support for modular composition. This tutorial introduces the Classic DEVS formalism in a bottom-up fashion, using a simple traffic light example. The syntax and operational semantics of atomic (i.e., non-hierarchical) models are introduced first. Coupled (i.e., hierarchical) models are introduced to structure and couple Atomic models. We continue to actual applications of DEVS, for example in performance analysis of queueing systems. All examples are presented with the tool PythonPDEVS, though this introduction is equally applicable to other DEVS tools. We conclude with further reading on DEVS theory, DEVS variants, and DEVS tools.

Introduction to the Discrete Event System Specification Formalism and Its Application for Modeling and Simulating Cyber-physical Systems / Gabriel Wainer (Carleton University) and Rhys Goldstein and Azam Khan (Autodesk Research)

The Discrete Event System Specification (DEVS) formalism is a set of conventions for specifying discrete event simulation models. In this tutorial, we introduce the core concepts of DEVS. First, we introduce a set of informal requirements from which a formal specification is to be developed. Then, we present different modeling conventions at different levels of abstraction. The tutorial exploits the DEVS formalism's support for modular model design. The concepts are discussed with an example of cyber-physical systems modeling and implementation, which can be used to understand the main concepts of the formalism.

LOGISTICS, SCM, TRANSPORTATION / R21

Complex Logistics Networks
Dave Goldsman (Georgia Institute of Technology)

A Case Study on Simulation of Railway Fleet Maintenance / Hervé Bury (ALSTOM) and Sven Spieckermann, Dirk Wortmann, and Florian Hübler (SimPlan AG)

This paper presents a joint simulation project in the area of railway fleet maintenance management. A simulation model was developed to understand and visualize the complex interaction in a railway system comprising rolling stock, depots, and maintenance guidelines. In many cases, requirements on such a system come from different sides, such as fleet operation (timetables and availability), maintenance engineering (maintenance regime), and depot management (depot restrictions). The paper describes the domain-specific challenge, the model, the implemented scheduling algorithm, and resulting insights. It, furthermore, describes how the model can be used for a variety of different use cases all along a railway project: from sizing to forecast and performance analysis and from initial tender theory check to operational risk analysis. Two real-world use cases are presented: West Coast Main Line and TransPennine Express, both in the United Kingdom.

Improving the Performance of a Logistics Assistance System for Materials Trading Networks by Grouping Similar Actions / Markus Rabe, Dominik Schmitt, and Majsa Ammouriova (TU Dortmund University)

Decision makers (DMs) for logistics networks (LNWs) have the complex task of maintaining their networks in good conditions while internal and external demands are changing. Therefore, the DMs need to identify promising actions in order to adapt to the LNW's changing state, e.g., increasing the stock level of stock keeping units (SKUs). The authors have developed a logistics assistance system (LAS) that automatically alters the LNW's model, for improving it under changing conditions, by applying actions and evaluating their effects on the LNW's performance. Promising actions are suggested to the DM. As the LNW grows in size, the number of potential actions increases and therefore, the response time of the LAS increases as well under the additional computational burden. In this paper, the authors describe a novel concept for reducing the number of actions by grouping similar actions together, leading to faster convergence and shorter response time of the LAS.

Utilizing Domain-specific Information for the Optimization of Logistics Networks / Markus Rabe, Majsa Ammouriova, and Dominik Schmitt (TU Dortmund University)

Continuously maintaining a logistics network (LNW) in good condition is a challenging task for decision makers. For purposes of improving an LNW's performance, promising actions need to be identified, such as the centralization of a stock keeping unit (SKU). In order to support the decision maker, the authors have developed a logistics assistance system (LAS) based on discrete-event simulation. With an increasing size of the LNW, the response time of such an LAS increases exponentially. In this paper, the authors present an approach for utilizing domain-specific information to guide the search for promising actions and, therefore, reduce the LAS's response time. The given examples show that the LAS's response time can be decreased. For example, the approach reduces the number of iterations needed by an evolutionary algorithm to converge.

MASM / R14

Sustainabilty and Productive Improvement Applications
Thomas Ponsignon (Infineon Technologies AG)

Flexibility as an Enabler for Carbon Dioxide Reduction in a Global Supply Chain: A Case Study from the Semiconductor Industry / Abdelgafar Ismail Mohammed Hamed, Hans Ehm, and Thomas Ponsignon (Infineon Technologies AG) and Beril Bayer and Kamil Erkan Kabak (Izmir University of Economics)

Due to the significant rise in environmental awareness of companies and customers for the past few years, research on how to optimize business with respect to carbon dioxide (CO2) emission has gained more attention and importance. This paper investigates how flexibility can be an enabler for CO2 reduction over a global production network especially in a capital intensive and high volatile market like the semiconductor one. We tested this hypothesis with discrete-event simulation experiments based on a case study obtained from a semiconductor company. The study indicates that global supply chains (SCs), like those in the semiconductor industry, should be equipped with a certain level of flexibility to cope with demand volatility if the CO2 burden due to transportation is low compared to those due to manufacturing. This flexibility provides ecological benefits to companies in reducing the carbon footprint of their products.

Electricity Power Cost-aware Scheduling of Jobs on Parallel Batch Processing Machines / Jens Rocholl and Lars Mönch (University of Hagen) and John Fowler (Arizona State University)

We discuss a bicriteria scheduling problem for parallel identical batch processing machines in semiconductor wafer fabrication facilities (wafer fabs). Only jobs that belong to the same family can be batched together. The performance measures of interest are the total weighted completion time and the electricity power cost. Unequal release dates of the jobs are taken into account. The jobs can have non-identical sizes. We provide a Mixed Integer Linear Programming (MILP) formulation for the general setting. Moreover, we analyze the special case where all jobs have the same size, the maximum batch size is an integer multiple of this job size, and all jobs are available at time zero. We

prove certain properties of Pareto-optimal schedules for this special case. These properties lead to a MILP formulation that is more tractable than the one for the general setting. We perform computational experiments with the εconstraint method for both formulations.

Re-enactment Simulation for Buffer Size Optimization in Semiconductor Back-End Production / Jelle Adan (Nexperia), Stephan Sneijders (Delft University of Technology), and Alp Akcay and Ivo Adan (Eindhoven University of Technology)

In this work, we propose a re-enactment simulation-based optimization method to determine the minimal total buffer capacity in an assembly line required to meet a target throughput. A distinguishing feature is the use of real-time event traces, in a fast fluid flow simulation model. Employing real-time event traces avoids the necessity to make restrictive modeling assumptions. The fluid simulation is combined with a multi start search algorithm. To demonstrate its effectiveness, the method is applied to a real-world use case in lead frame based semiconductor back-end manufacturing. This use case considers an assembly line consisting of six machines, for which the proposed method determines optimal buffer size configurations within several minutes of computational time.

MILITARY APPLICATIONS / R17

Open Military Challenges
Robert Siegfried (Aditerna GmbH)

Hybrid Conflict Modeling / Mariusz Balaban (U.S. Army) and Paweł Mielniczek (University of Warsaw)

Although representations of many elements of hybrid conflict can be identified in the literature, its more holistic view needs more research. The use of Modeling and Simulation (M&S) to represent past and emerging hybrid conflicts can aid in better understanding of their factors and deceptive mechanisms leading to the accumulative effects. Gained understanding could help in preventing, mitigating, and winning hybrid conflicts. Because hybrid conflict is not an entirely new phenomenon this paper offers a few historical examples followed by an attempt to clarify relevant to hybrid conflicts terms. Causal loop diagram (CLD) is used to represent theoretical model of hybrid conflict, while Dynamic Bayesian Network (DBN) demonstrates its implementation. The final section discusses a coordinated defense approach against hybrid threats and needs for a better hybrid conflict representation.

Simulation-based Evaluation on Integrating Additive Manufacturing Capability in a Deployed Military Environment / Timothy A. Moore (U.S. Military Academy) and Brandon M. McConnell and James R. Wilson (NC State University)

This article develops a data-driven forecast of repair parts for the M109A6 Paladin self-propelled 155 mm howitzer, and this forecast drives a discrete-event simulation to assess requirements for Additive Manufacturing (AM) to be a feasible part of the U.S. Army's expeditionary supply chain. Actual part demand from the initial invasion of Iraq in 2003 during Operation Iraqi Freedom (OIF) feeds a sample-path-based forecasting method to obtain part demand for each scenario. A simulation of a conceptualized deployed Army 3D-printing facility integrated into the supply chain evaluates the performance and feasibility of the different operational policies. Results indicate current technology could support one battery (or smaller unit) for parts below 100 cubic inches while keeping performance comparable with OIF. These results are incorporated in realistic recommendations for how the Army can potentially improve its supply chain practices with this progressive technology.

Open Challenges in Building Combat Simulation Systems to Support Test, Analysis, and Training / Raymond R. Hill (Air Force Institute of Technology), Andreas Tolk (The MITRE Corporation), and Douglas D. Hodson and Jeremy R. Millar (Air Force Institute of Technology)

High expectations to leverage Modeling and Simulation (M&S) capabilities to support operational testing, systems analysis and user/operator training is motivated by a number of factors. As the complexities of new operations, such as multi-domain operations and operations in highly contested area operations, can no longer be tested and trained in live environments, leveraging M&S capabilities efficiently is paramount. In this paper, we use the differentiation of combat simulation requirements in terms of functional (e.g., model fidelity) and non-functional (e.g., real-time, distributed) characteristics to define a trade

space to highlight challenges in relation to simulation purpose. 5th generation weapon systems require lots of data with high fidelity, depending on the purpose of the simulation. As functional and non-functional characteristics are interdependent, the design of supporting simulation systems must be well aligned with the purpose when developed, and is constraining possible purposes to be supported once it is developed.

MODELING METHODOLOGY / R26

Parameter Estimation
Jose J. Padilla (Old Dominion University, VMASC)

Imcsim: Parameterized Performance Prediction for Implicit Monte Carlo Codes / Gopinath Chennupati, Stephan Eidenbenz, Alex Long, Olena Tkachenko, and Joseph Zerr (LANL) and Jason Liu (Florida International University)

Monte Carlo techniques to radiation transport play a significant role in modeling complex astrophysical phenomena. In this paper, we design an application model (IMCSim) of an Implicit Monte Carlo (IMC) particle code using the Performance Prediction Toolkit (PPT), a discrete-event simulation-based modeling framework for predicting code performance on a large range of parallel platforms. We present validation results for IMCSim. We then use the fast parameter scanning that such a high-level loop-structure model of a complex code enables to predict optimal IMC parameter settings for interconnect latency hiding. We find that variations in interconnect bandwidth have a significant effect on optimal parameter values. Our results suggest potential value using IMCSim as a pre-step to substantial IMC runs to quickly identify optimal parameter values for the specific hardware platform on which IMC runs.

On-line Parameter Estimation of Reduced-Order Models for Buildings Energy Dynamics Using the Modulating Function Method / Ana Ionesi and Jerome Jouffroy (University of Southern Denmark)

This paper considers parameter estimation of a reduced-order model (ROM) for building energy dynamics using the modulating function (MF) method. After briefly presenting a model of building dynamics, we recall the MF method and present a way of determining a modulating function directly from the available data instead of defining it a priori. Then, we look at the application of this method in a case study, where actual weather-based data (solar radiation and outdoor ambient temperature) is used. The results together with the advantages of the MF underline the potential of the proposed algorithm.

A Non-parametric Approach to Simulate Panel Data / Bahram Yousefi, Mohanad Ajina, Muhammad Imran, and Kathryn Laskey (George Mason University)

Real world multivariate data mostly contains correlation structure because generally some variables tend to have a similar behavior or some dependency structure. This is due to the nature of data generation process. The variables can contain cross-sectional correlation, correlation between variables at a given time stamp, and temporal correlation, correlation between various observations of a given variable at various timestamps. Also, there are datasets which contain both cross-sectional and temporal correlations. Modeling of such correlation structure in the data is important because it provides us the predictive power and affects the Machine Learning algorithms in various ways, due to relationships within variables. We propose a methodology to simulate a cyber activity dataset, containing both cross-sectional and temporal correlations, also called Panel dataset. The proposed methodology uses non-parametric approach to induce correlations among feature vectors and across time without disturbing the marginal distributions of features.

PROJECT MANAGEMENT AND CONSTRUCTION / R24

Construction and Maintenance Simulation
Reza Akhavian (California State University East Bay)

Evaluation of Wearable Sensors to Quantify Construction Workers Muscle Force: An Ergonomic Analysis / Shahin Jahanbanifar and Reza Akhavian (California State University East Bay)

Construction industry has one of the highest rates of bodily injuries including serious Work-related Musculoskeletal Disorders (WMSDs). The Occupational Safety and Health Administration (OSHA) identifies force level as a risk in-

dicator associated with WMSDs. Without direct measurement, quantifying the force exerted during a given task performed by workers is difficult, if not impossible. Therefore, an indirect and non-intrusive way of identifying excessive force applied during physical tasks can effectively reduce the risk of WMSD injuries. In this research, a series of physical activities involving pushing and pulling are simulated by the research team in laboratory-scale experiments. The exerted force is measured using a work simulator tool and accelerometer data is collected from a smartphone sensor affixed on the working arm. Artificial Neural Network is trained with the accelerometer data and the force levels. Testing results indicate that the trained model can predict the force level with over 87.5% accuracy.

Improving Tunneling Simulation using Bayesian Updating and Hidden Markov Chains / Michael Werner, Wenying Ji, and Simaan AbouRizk (University of Alberta)

Ground conditions remain an uncertain factor in tunneling projects, complicating the ability of practitioners to reliably estimate project productivity and, in turn, duration. This study proposes a Bayesian-based approach to incorporate real-time project data into simulation-based ground prediction models to improve prediction accuracy. Changes in ground conditions are modeled using a Hidden Markov Model, which is updated with actual project data using the Baum-Welch algorithm. The prediction model is then incorporated in Simphony. NET to enhance simulation of tunneling construction operations. A case study conducted in Edmonton, Canada, demonstrates that the proposed approach is capable of incorporating real-time data in a manner that resulted in enhanced duration prediction accuracy.

Actor-Oriented Optimization Model for Maintenance Tasks / Sven Tackenberg (OWL University of Applied Sciences) and Sönke Duckwitz (RWTH Aachen University)

This paper introduces an extension of the well-established Resource-Constrained Project Scheduling Problem (RCPSP) to apply it to maintenance problems of highly frequented infrastructure. A major complication of the observed scheduling problem is that the infrastructure is only temporarily available for maintenance and repair work during the shift of the workforce. A multi-criteria evolutionary algorithm with a novel problem representation is introduced which is capable of revising technician-task allocations whereas the duration of the task may be stochastic. The main objective is to develop shift plans which maximize the utilization rate of technicians due to a minimization of waiting times caused by the use of the infrastructure through other actors. The results of the already implemented core algorithm for an actor-oriented model illustrate a fast convergence towards an optimal work allocation within a team as well as an efficient sequence of tasks.

SIMULATION FOR A NOBLE CAUSE / R22

Humanitarianism - II
George Miller (MOSIMTEC)

A Management Tool Based on Discrete Event Simulation for Humanitarian Support / Vlademir Fazio Santos (FEEC Unicamp), Edson Luiz Ursini and Paulo Sergio Martins (School of Technology of Unicamp), and Michel Daoud Yacoub (FEEC Unicamp)

Humanitarian aid is material or logistical assistance provided for humanitarian purposes, typically in response to humanitarian crises including natural disasters and man-made disaster. Humanitarian assistance requiring short response time windows in almost the whole world may be subject to long queues due to managing problems, e.g., the lack of control and/or inefficient infrastructure. This work tackles such challenge by proposing a low-cost planning and managing model and method based on a discrete-event simulation mirror connected through WEB tools to a near or far management level. The usual configuration of parallel servers (for instance, supported by local RFID monitoring) is implemented by a discrete-event simulation model that is validated by Jackson Networks (and vice versa). The results show a flexible model that may identify bottlenecks in advance in order to accommodate traffic flow variations.

Simulation Model and Simulation-based Serious Gaming in Humanitarian Logistics / Robert de Souza, Linda William, Giuseppe Timperio, and Za'Aba Bin Abdul Rahim (National University of Singapore)

Humanitarian logistics has recently gained increasing attention from both academics and practitioners. Although various research groups have addressed theoretical and technical developments in humanitarian logistics, only a limited number of those can actually be generalized, extended, accessed, and understood by non-technical practitioners. To tackle these challenges, we develop a simulation model for humanitarian logistics preparedness and a simulation-based serious game to raise awareness and provide accessibility on humanitarian logistics research to a wider audience. The simulation model aims to optimize the network configuration for prepositioning stocks of life-saving goods in Indonesia, while the game aims to provide a risk-free environment where players can craft various strategies to plan and deploy effective humanitarian operations.

Developing an Agent-based Simulation Model of the Use of Different Communication Technologies in Inter-Organizational Disaster Response Coordination / Susan Aros and Deborah Gibbons (Naval Postgraduate School)

Our research focuses on communications among a variety of organizations that coordinate their rapid responses to catastrophic disasters. Within the context of FEMA's National Response Coordination Center, we constructed an agent-based simulation model of the inter-organizational communications happening via their Web-based Emergency Operations Center, email, phone calls, and face-to-face conversations as the support requests were addressed and fulfilled. We developed our model based on FEMA documentation, observations, interviews, and exercise data. In this paper we outline our model development process and provide details about our simulation model to highlight and address some of the particular challenges one faces when developing simulation models of disaster response activities. We describe what specific aspects of communication media and situational factors our model was developed to test, and also present the design and select results of our first research experiment using this model.

SIMULATION OPTIMIZATION / J2

SO in Smart Cities

Josep Casanovas (UPC, Barcelona Supercomputing Center)

Stochastic Optimization for Feasibility Determination: An Application to Water Pump Operation in Water Distribution Network / Yi-An Tsai (Arizona State University), Riccardo Perego (University of Milano-Bicocca), Giulia Pedrielli (Arizona State University), Zelda B. Zabinsky (University of Washington), Antonio Candelieri (University of Milano-Bicocca), Hao Huang (Yuan Ze University), and Logan Mathesen (Arizona State University)

Water Distribution Networks are a particularly critical infrastructure for the high energy costs and frequent failures. Variable Speed Pumps have been introduced to improve the regulation of water pumps, a key for the overall infrastructure performance. This paper addresses the problem of analyzing the effect of the VSPs regulation on the pressure distribution of a WDN, which is highly correlated to leakages and energy costs. Due to the fact that water network behavior can only be simulated, we formulate the problem as a black box feasibility determination, which we solve with a novel stochastic partitioning algorithm, the Feasibility Set Approximation Probabilistic Branch and Bound, that extends the algorithm previously proposed by two of the authors. We use, as black box, EPANet, a widely adopted hydraulic simulator. The preliminary results, over theoretical functions as well as a water distribution network benchmark case, show the viability and advantages of the proposed approach.

Simulation-based Headway Optimization for a Subway Network: A Performance Comparison of Population-based Algorithms / David Schmaranzer, Roland Braune, and Karl F. Doerner (University of Vienna)

We present a study on simulation-based optimization for the Viennese subway system. The underlying discrete event simulation model has several stochastic elements like time-dependent demand and turning maneuver times, direction-dependent vehicle travel and passenger travel as well as transfer times. Passenger creation is a Poisson process which uses hourly origin-destination-matrices based on mobile phone data. The number of waiting passengers on platforms and within vehicles are subject to capacity restrictions. As a microscopic element, passenger distribution along platforms and within vehicles is considered. There are trade-offs between service quality (e.g. waiting time) and costs (e.g.

fleet mileage). This bi-objective optimization problem is transformed into a single-objective one by normalization and scalarization. The goal is to find optimal time-dependent headways. Computational experience is gained from 48 test instances which are based on real-world data. Several population-based evolutionary algorithms were applied. The covariance matrix adaptation evolution strategy (CMA-ES) performed best.

Optimizing Simulation on Shared-Memory Platforms: The Smart Cities Case / Mauro Ianni, Romolo Marotta, Davide Cingolani, and Alessandro Pellegrini (Sapienza, University of Rome) and Francesco Quaglia (University of Rome «Tor Vergata»)

Modern advancements in computing architectures have been accompanied by new emergent paradigms to run Parallel Discrete Event Simulation models efficiently. Indeed, many new paradigms to effectively use the available underlying hardware have been proposed in the literature. Among these, the Share-Everything paradigm tackles massively-parallel shared-memory machines, in order to support speculative simulation by taking into account the limits and benefits related to this family of architectures. Previous results have shown how this paradigm outperforms traditional speculative strategies (such as data-separated Time Warp systems) whenever the granularity of executed events is small. In this paper, we show performance implications of this simulation-engine organization when the simulation models have a variable granularity. To this end, we have selected a traffic model, tailored for smart cities-oriented simulation. Our assessment illustrates the effects of the various tuning parameters related to the approach, opening to a higher understanding of this innovative paradigm.

SIMULATION STANDARDS AND REPRODUCIBILITY / R15

Issues in Simulation Reproducibility
Guodong Shao (National Institute of Standards and Technology)

Generating Simulation Experiments Based on Model Documentations and Templates / Andreas Ruscheinski, Kai Budde, Tom Warnke, Pia Wilsdorf, Bjarne Christian Hiller, Marcus Dombrowsky, and Adelinde M. Uhrmacher (University of Rostock)

An increasing number of approaches for specifying and executing simulation experiments emphasizes the desire to make this part of modeling and simulation studies explicit, and thus, also easier to replicate. We take this one step further by automatically generating simulation experiment specifications from documentations. Based on a template-based approach and documentations, we show how simulation experiment specifications can be generated and executed for experiments, such as statistical model checking and sensitivity analysis, and we identify crucial challenges.

ODD+P: Complementing the ODD Protocol with Provenance Information / Oliver Reinhardt, Andreas Ruscheinski, and Adelinde Maria Uhrmacher (University of Rostock)

Provenance information about a simulation model is information about people, artifacts, and processes that have contributed to its generation. It increases trust into the quality and validity of simulation models. Model documentation standards such as the ODD protocol have a similar goal, but are mostly concerned with “what has been generated”, and less with “how it has been generated”. Complementing ODD with provenance information offers a more structured approach to the “what” and fills the gap regarding the “how”. Thereby, simulation experiments play a crucial role, and are treated as first class artifacts, as are simulation models, data sources, and theories. The compliance to the Open Provenance Model allows using established tools for inferring the model’s origin. The approach is of particular value for models that are based on various data sources, theories, and earlier models, as we will show based on a model about migration from Senegal to Europe.

Applying the STRESS Guidelines for Reproducibility in Modeling & Simulation: Application to a Disease Modeling Case Study / Simon JE Taylor and Anastasia Anagnostou (Brunel University London), Christine Currie and Thomas Monks (University of Southampton), Stephan Onggo (Trinity College Dublin), Martin Kunc (The University of Warwick), and Stewart Robinson (Loughborough University)

It is arguably difficult to reproduce the results of published work in Modeling & Simulation (M&S). Authors have certainly raised concerns about this issue and

attempts by journals and conferences are being made to improve the situation. As part of a movement to tackle reproducibility in M&S, the Strengthening The Reporting of Empirical Simulation Studies (STRESS) reporting checklists were introduced in 2018. The STRESS guidelines aimed to improve knowledge management in industry and to maximize the chance that all important M&S details are included when writing up simulation research for publication. We extend this work by providing an applied example of using the STRESS-ABS checklist for documenting an Agent Based Simulation model. It is hoped that an applied example will both encourage and guide authors and practitioners to improve their reporting.

VENDOR TUTORIALS / R25

Anylogic

New AnyLogic Material Handling Library / Pavel Lebedev and Nikolay Churkov (The AnyLogic Company)

The new AnyLogic Material Handling Library simplifies the simulation of complex manufacturing systems and operations. It can be used to design detailed models of production and storage facilities and manage material workflows inside four walls. The digital factory model, created with the material handling simulation toolkit, can help test and optimize production, transportation, and inventory policies, as well as reduce possible errors and material flow delays on the factory floor. In conveyor network models, created with the Material Handling Library, users can apply default or set up custom routing strategies for material items, industrial robots, manufacturing machines, and operators. Simulated AGVs and other transporters automatically avoid collisions, detect possible deadlocks, and resolve them.

AnyLogic Cloud — Cloud-based Simulation Analytics / Andrei Borshchev and Nikolay Churkov (The AnyLogic Company)

AnyLogic Cloud is a web service that allows users to run simulation models online on any device using just a web browser, and share the output results with colleagues and customers. It equips users with cloud-based simulation capabilities for setting up and running complex experiments, displaying results on custom dashboards, and providing online simulation analytics to clients. AnyLogic Cloud Subscription provides extended Cloud simulation capabilities with unlimited run time, additional computing resources, and access to external services. The open API functionality, available with the subscription, allows users to design custom web interfaces for simulation models. For companies subject to strict operating guidelines we offer AnyLogic Private Cloud. Its infrastructure can be hosted on-site, at company's data center, and integrated in company's workflows, so that AnyLogic models can be deployed throughout the company. The dedicated environment of the Private Cloud gives complete control over the data and its processing.

Monday 3:30p.m.-5:00p.m.

ADVANCED TUTORIALS / R23

Selection and Ranking
Jeff Parker (Naval Postgraduate School)

Guarantees on the Probability of Good Selection / David J. Eckman and Shane G. Henderson (Cornell University)

This tutorial provides an overview of guarantees on the probability of good selection (PGS), i.e., statistical guarantees on selecting – with high probability – an alternative whose expected performance is within a given tolerance of the best. We discuss why PGS guarantees are superior to more popular, related guarantees on the probability of correct selection (PCS) under the indifference-zone formulation. We review existing procedures that deliver PGS guarantees and assess several direct and indirect methods of proof. We compare the frequentist and Bayesian interpretations of PGS and highlight the differences in how procedures are designed to deliver PGS guarantees under the two frameworks.

AGENT-BASED SIMULATION / R5

Home and Urban Planning
Mohsen Jafari Songhori (Tokyo Institute of Technology)

Simulating Daily Activities in a Smart Home for Data Generation / Jennifer Renoux and Franziska Klügl (Örebro University)

Smart Homes are currently one of the hottest topics in the area of Internet of Things or Augmented Living. In order to provide high-level intelligent solutions, algorithms for identifying which activities the inhabitants intend to perform are necessary. Sensor data plays here an essential role, for testing, for learning underlying rules, for classifying and connecting sensor patterns and to inhabitant activities, etc. However, only few and limited data sets are currently available. We present concepts and solutions for generating high-quality data using a flexible agent-based simulation tool. The basic idea is to integrate the simulation of a sensorized apartment with human behavior modelling based on constraint-based planning that produces a sequence of daily activities. The overall set-up is shown to generate data that exhibits the same relevant properties as data from a comparable real-world apartment.

chiSIM: An Agent-based Simulation Model of Social Interactions in a Large Urban Area / Charles M. Macal, Nicholson T. Collier, Jonathan Ozik, Eric R. Tatara, and John T. Murphy (Argonne National Laboratory)

Cities are complex, dynamic, evolving adaptive systems comprised of people as well as interconnected physical infrastructure. Simulation modeling can help us understand and shape the evolution of our cities. In this paper, we describe an agent-based simulation modeling framework applied to Chicago, called chiSIM (for the Chicago Social Interaction Model). Each person residing in Chicago is represented as an agent in chiSIM; all places where people can be located in Chicago also are represented. The model simulates the movements of people between locations on an hourly basis during the course of a typical day. Co-located agents engage in various kinds of social interactions, such as exchanging information, engaging in business transactions, or simply sharing physical proximity. We discuss technical approaches to largescale urban modeling including development of synthetic populations, efficiency gains through distributed processing, logging and analysis of simulation results, and visualization.

An Agent-based Simulation Framework for Supply Chain Disruptions and Facility Fortification / Xueping Li and Rodney Kizito (University of Tennessee, Knoxville) and Taynara de Paula Incerti (Federal University of Itajuba)

Fortifying facilities within a supply chain network can mitigate facility failures caused by disruptions. In this study we build an agent-based simulation model to study the r-interdiction median problem with fortification (RIMF), considering two types of facility disruptions: naturally-caused and human-caused disruptions. The objective of this study is to develop a simulation model that analyzes facility disruption and fortification as a repeated Stackelberg competition, where fortification decisions are made anticipating disruptions. The most important facilities - those with the largest demand coverage - are fortified, while the next most important facilities - those not fortified due to fortification resource limitations - are successfully disrupted. In addition, the study provides event-by-event updates of the fortifying, disrupting, and recovering processes, as well as how these events affect the total network cost over the course of the simulation; thus paves the way for a future study on how to make optimal fortification decisions.

ANALYSIS METHODOLOGY / CONGRESS HALL

Simulation Uncertainty Quantification
M. Ben Feng (University of Waterloo)

Estimation Of moment Independent Importance Measures Using a Copula And Maximum Entropy Framework / Pierre Derennes (UPS), Jérôme Morio (ONERA), and Florian Simatos (ISAE SUPAERO)

The moment-independent sensitivity analysis technique introduced by E. Borgonovo has gained increasing attention to characterize the uncertainty of complex systems and optimize their reliability. The estimation of corresponding indices is a challenging task. This paper aims at presenting a new estimation scheme valid for dependent model inputs. This scheme is build on the copula representation of indices and uses maximum entropy methods to estimate

this copula. Accuracy of the proposed method is evaluated through numerical simulations and is compared to two competitive methods, namely an importance sampling based approach and a second one which uses the Nataf transformation.

Revisiting Direct Bootstrap Resampling for Input Model Uncertainty / Russell R. Barton (The Pennsylvania State University), Henry Lam (Columbia University), and Eunhye Song (The Pennsylvania State University)

Metamodel-based bootstrap methods for characterizing input model uncertainty have disadvantages for settings where there are a large number of input distributions, or when using empirical distributions to drive the simulation. Early direct bootstrapping of empirical distributions did not take into account the distinction between intrinsic and extrinsic variation in the resampled quantities. When the intrinsic uncertainty is large, the result is overcoverage of the bootstrap percentile intervals. We explore ways of accounting for both sources in direct bootstrap characterization of input model uncertainty, and study the impact on confidence interval (CI) coverage. Four new bootstrap-based CIs for the expected simulation output under the unknown true distribution are proposed, basic shrinkage CI, percentile shrinkage CI, basic hierarchical bootstrap CI, and percentile hierarchical bootstrap CI, and their empirical performances are demonstrated using an example.

Uniform Convergence Of Sample Average Approximation With Adaptive Multiple Importance Sampling / Ben Feng (University of Waterloo), Alvaro Maggiar (Amazon.com), and Jeremy Staum and Andreas Waechter (Northwestern University)

We study sample average approximations under adaptive importance sampling in which the sample densities may depend on previous random samples. Based on a generic uniform law of large numbers, we establish uniform convergence of the sample average approximation to the function being approximated. In the optimization context, we obtain convergence of the optimal value and optimal solutions of the sample average approximation.

AVIATION MODELING AND ANALYSIS / R4

Airport Operations
Bruno Desart (EUROCONTROL)

Noise Analysis of Aircraft Departure Procedures Using Monte Carlo Simulation / Tommy Smits, Sander Hartjes, and Mihaela Mitici (Delft University of Technology)

During arrival and departure procedures at an airport, aircraft generate noise. High levels of noise during these terminal procedures can have a negative impact on the communities located near the airport. We assess the impact of the noise generated by a standard instrument departure of a twin-engine narrow body mid-range aircraft over the communities nearby Amsterdam Airport Schiphol, the Netherlands. During the departure procedure, we consider a stochastic flight trajectory that is subject to lateral position errors. We estimate, using Monte Carlo simulation, the distribution of the sound exposure level and of the number of awakenings generated by a departure. We also identify the residential areas where the number of awakenings are overestimated or underestimated, when comparing a stochastic and a deterministic departure approach. Lastly, we approximate the distribution of the noise level for a generic aircraft departure, which can be further employed for further optimization of departure procedures.

Prediction of Aircraft Boarding Time using LSTM Network / Michael Schultz and Stefan Reitmann (German Aerospace Center, Institute of Flight Guidance)

Reliable and predictable ground operations are essential for 4D aircraft trajectories. Uncertainties in the airborne phase have significantly less impact on flight punctuality than deviations in aircraft ground operations. The ground trajectory of an aircraft primarily consists of the handling processes at the stand, defined as the aircraft turnaround, which are mainly controlled by operational experts. Only the aircraft boarding, which is on the critical path of the turnaround, is driven by the passengers' experience and willingness or ability to follow the proposed procedures. We propose a machine learning approach predict the boarding time. A validated boarding simulation provides data input for a recurrent neural network approach (discrete time series of boarding progress). In particular we use a Long Short-Term Memory model to learn the characteristic passenger behaviors over time.

Simulating Passenger's Shopping Behavior at Airport with a Conceptual Agent-based Model / Yimeng Chen, Cheng-Lung Wu, Pau Long Lau, and Nga Yung Agnes Tang (The University of New South Wales)

Airport retail revenue has long been recognized as a critical revenue stream to ensure an airport's financial sustainability and stability. However, there is a lack of simulation model on how airport terminal could be better designed to facilitate this vital revenue stream. This paper presents a conceptual agent-based simulation model on passengers shopping behavior in the airport context. This model attempts to investigate the relationship between terminal design and retail performance through different scenarios studies. Results show that finger pier terminal shape can have a negative impact on retail revenue if shops are decentralized. Terminal with centralized shopping areas also performed better than a terminal with decentralized shopping area. Future research directions were proposed at the end to improve the existing simulation model with the aim of making it an essential evaluation tool for future terminal design.

CASE STUDIES / R2

Manufacturing & Strategy
Leonardo Chwif (Escola de Engenharia Mauá, Mauá Institute of Technology)

Application System Based on Simulation for Outfitting Fabrication of Offshore Structure / Hojung Kim, Junggoo Park, Hyunman Cho, and Heeyoung Heo (Samsung Heavy Industries)

Timely installation of fittings is a vital element of successful construction of offshore structures. In particular, pipe spools take up a large part of installation work of the entire fittings. Most of the pipe spools are fabricated and supplied by partner companies. Whereas the procurement and supply of raw materials are carried out by Samsung Heavy Industries (SHI). Therefore, it is necessary to not only manage the timely receipt of raw materials, but also check a bill of materials (BOM). Inventory and delivery schedule are considered to forecast a possibility of outfitting fabrication. This paper discusses an example of the application of an algorithm that supports schedule confirmation and decision making when forecasting a schedule.

Higher Production Plan Realization through Dynamic Simulation / Amit Kumar and Sumit Kumar (ITC Infotech Ltd)

Production plans are based on fair assumptions of process performance and all operation parameters are taken as averages. There are a number of events that happen in any manufacturing setup during the course of production like periodic delivery of raw materials or changeovers on a machine. The interaction between these events is non-linear and cannot be easily visualized. As a result of which most of the production plans in any company have only a limited realization. This paper provides an example of how simulation using Anylogic has been applied in one such plant scenario to visualize the plan outcome.

Agent-based Simulation Marketing Mix Model for Budget Management in Cosmetic Industry / Francisco Lonardi, Brian Erik Ovrum, Mateo Roberto Dennehy, and Patricio Ivan Pipp (Accenture Digital)

A worldwide leading company in the cosmetic industry was dealing with great challenges regarding adapting its positioning strategy to the dynamically changing behaviors of the market. The company needed to decide where to invest its marketing budget to optimize its revenue and was using different traditional marketing mix models without any success. A marketing mix model was developed using agent-based modeling to predict the market's reaction to a given distribution of a certain budget among the different touchpoints available. This innovative model uses market information and consumer information collected from surveys to estimate the company's sales, level of awareness and level of consideration given its distributed investment. The tool was implemented as part of the marketing plan decision making process, providing the ability to test different scenarios and generate quantitative analysis of its results.

JOINT SESSION: CYBER-PHYSICAL SYSTEMS & ENVIRONMENT AND SUSTAINABILITY APPLICATIONS / R11

Network Protection
Zhi Zhou (Argonne National Laboratory)

Reducing Power Consumption in Smart Campus Network Applications through Simulation of High-Priority Service, Traffic Balancing, Prediction and Fuzzy Logic / Jose Roberto Emiliano Leite, Flavio Rubens Massaro, Paulo Sergio Martins, and Edson Luiz Ursini (UNICAMP, State University of Campinas)

In this work, we tackle power consumption reduction of battery-dependent devices in a smart campus (including hospital) application. These devices are connected by networked systems which may be subject to fluctuation of the message delays that control essential equipment. We show through five case studies using discrete event simulation, that power consumption may be reduced using proper prioritization and balancing of the network emergency traffic. A predictor algorithm and a fuzzy logic controller was used to indicate the level upon which the system must switch off the load in order to reduce power consumption. The analysis of a case study shows that a considerable reduction in power consumption was achieved through the reduction of message delays and also due to the fuzzy control of AC and lighting equipment.

VOTNet: Hybrid Simulation of Virtual Operational Technology Network for Cybersecurity Assessment / Sajal Sarkar (National University of Singapore, PGCIL) and Anand Agrawal, Yong Meng Teo, and Ee-Chien Chang (National University of Singapore)

Cybersecurity assessment in automation requires a modeling and simulation framework to study the complex relationships between the cyber-based control mechanisms and the power systems. A real power system is not ideal for such an assessment due to potential disruption in operation. In this paper, we propose a simulation model of a virtual operational technology (OT) network in power system automation for cybersecurity assessment. The proposed simulation model is modularized with key components including power system and process, communication, automation, and enterprise network. We discuss Virtual OT Network (VOTNet), a specific instance of the model, in terms of simulated and emulated systems such as programmable logic controller, computing systems, control centers, and software. We evaluate VOTNet under two use cases: different attack scenarios and scalability vs. attack surface to study the impacts of cyber attacks. Particularly, unauthorized access, data manipulation in PLC, and denial of service in SCADA communication are demonstrated.

Simulation-based Stochastic Programming to Guide Real-time Scheduling for Smart Power Grids under Cyber Attacks / Yuan Yi (Rensselaer Polytechnic Institute), Wei Xie (Northeastern University), and Zhi Zhou (Argonne National Laboratory)

With the integration of renewable energy and advanced communication technologies, smart power grids can enhance the cost-efficiency and reliability of energy generation, transmission, and distribution. The communication network connecting numerous remotely distributed generators, devices, and controllers plays a vital role in the control of power grids. However, it is vulnerable to cyber attacks. In particular, because of its frequency and lasting impact, the Distributed Denial of Service (DDoS) attack poses an important threat to smart power grids. This paper presents a simulation-based stochastic programming approach to guide the unit commitment and economic dispatch decisions, which accounts for the prediction uncertainty of wind power and the impact from DDoS attacks. The case study demonstrates that the proposed approach can lead to a more cost-efficient and reliable operational decision guidance for smart power grids.

HEALTHCARE APPLICATIONS / R12

Emergency Medical Service Systems
Ettore Lanzarone (CNR-IMATI)

A Recursive Optimization-Simulation Approach for the Ambulance Location and Dispatching Problem / Ettore Lanzarone and Enrico Galluccio (Consiglio Nazionale delle Ricerche (CNR)), Valérie Bélanger (HEC Montréal), and Vittorio Nicoletta and Angel Ruiz (Université Laval)

The Ambulance Location and Dispatching Problem (ALDP) identifies the location of the available ambulances and the best dispatching policy to minimize the response times to answer the calls. However, the uncertain nature of the emergency calls makes it impossible to know in advance if the ambulance identified by the dispatching policy is available or not upon a call arrival. Thus, the probability that a vehicle is busy when a call arises, denoted as busy fraction, is usually considered in the literature. Probabilities can be estimated in several manners, but simulation seems to be well suited for this purpose. In this work, we propose four Recursive Optimization-Simulation Approaches to estimate the ALDP busy fraction, and we apply them to a set of realistic instances. Numerical results confirm that the most sophisticated and computing demanding approaches offer a better performance.

Simulation Based Prediction of the Near-Future Emergency Medical Services System State / Tobias Andersson Granberg and Hien Thi Ngoc Nguyen (Linköping University)

An ambulance dispatcher decides which ambulances to allocate to new calls, and how to relocate ambulances in order to maintain a good coverage. Doing this, it is valuable to have information about the future expected response times in different parts of the area of responsibility, as well as the expected number of available ambulances. We present a simulation model that can be used to predict this, and compare the results to a naïve forecasting model. The results show that while it is difficult to accurately predict the future system state, the simulation based prediction manages this better than the naïve model.

A Simulation and Online Optimization Approach for the Real-time Management of Ambulances / Roberto Aringhieri, Simone Bocca, Luigi Casciaro, and Davide Duma (University of Turin)

Emergency Medical Service is one of the most important health care services as it plays a vital role in saving people's lives and reducing the rate of mortality and morbidity. A peak of emergency demand can determine overcrowding at the emergency department. In this operative context, a challenge is the definition of proper real-time dispatching, routing and redeployment policies (DRRP) in such a way to maximize the number of emergency requests served within a time threshold, and to minimize the waiting times. The contribution of this paper is twofold. The former is a simulation model capable to deal with the real-time management of the ambulances, and to generate new ad hoc instances. The latter is a set of simple online algorithms to implement several DRRP. An extensive comparison among different DRRP is also provided.

HYBRID SIMULATION / R6

Hybrid Simulation and Analytics
David Bell (Brunel University London)

Symbiotic Simulation System: Hybrid Systems Model Meets Big Data Analytics / Bhakti Stephan Onggo (Trinity College Dublin), Navonil Mustafee (University of Exeter), Angel A. Juan (Universitat Oberta de Catalunya), Owen Molloy (National University of Ireland Galway), and Andi Smart (University of Exeter)

Symbiotic simulation is one of Industry 4.0 technologies that enables interaction between a physical system and the simulation model that represents it as its digital twin. Symbiotic simulation is designed to support decision making at the operational levels by making use of real- or near real- time data that is generated by the physical system, which is used as an input to the simulation model. From the modeling perspective, a symbiotic simulation system comprises a hybrid systems model that combines simulation, optimization and machine learning models as well as a data acquisition module and an actuator. The actuator is needed when the symbiotic simulation system is designed to directly control the physical system without human intervention. This paper reviews the components of a symbiotic simulation system from the perspective of hybrid systems modeling and highlights research questions needed to advance symbiotic simulation study.

Presenting a Hybrid Processing Mining Framework for Automated Simulation Model Generation / Mohammed Mesabbah and Susan Mckeever (Dublin Institute of Technology, CeADAR)

Recent advances in information technology systems have enabled organizations to store tremendous amounts of business process data. Process mining offers

a range of algorithms and methods to analyze and extract metadata for these processes. This paper presents a novel approach to the hybridization of process mining techniques with business process modelling and simulation methods. We present a generic automated end-to-end simulation framework that produces unbiased simulation models using system event logs. A conceptual model and various meta-data are derived from the logs and used to generate the simulation model. We demonstrate the efficacy of our framework using a business process event log, achieving reduction in waiting times using resource reallocation. The intrinsic idea behind our framework is to enable managers to develop simulation models for their business in a simple way using actual business process event logs and to support the investigation of possible scenarios to improve their business performance.

Building Partial Differential Equations Models Using Cell-DEVS / Gabriel Wainer and Cristina Ruiz-Martin (Carleton University) and Rodrigo Castro (Universidad de Buenos Aires)

The study of complex systems usually requires hybrid simulations because they have components that are continuous in nature and other that are discrete. It has been proved that DEVS is s a common denominator to combine different Modeling and Simulation methodologies (such as Petri Nets, Cellular Automata, Modelica etc.). We present a cellular model solution to solve PDEs as an extension of classical numerical methods combined with the Cell-DEVS formalism. We explain how to use Cell-DEVS to solve PDEs, focusing on two examples: the PDEs of a Heat Diffusion Process solved with the Method of Lines, and the Shallow Water Equations solved using the Lax-Wendroff method. We will discuss the advantages of solving PDEs with Cell-DEVS, in particular its integration with other hybrid models.

INTRODUCTORY TUTORIALS / R31

Participative Simulation (PartiSim)
Lucy E. Morgan (Lancaster University)

Participative Simulation (PartiSim): A Facilitated Simulation Approach for Stakeholder Engagement / Antuela Tako (Loughborough University) and Kathy Kotiadis (Canterbury Christ Church University)

Facilitated discrete event simulation offers an alternative mode of engagement with stakeholders (clients) in simulation projects. It is particularly beneficial when modeling systems with complex behavior, involving many stakeholders with plurality of opinions and objectives. PartiSim - short for Participative Simulation - is a facilitated modeling approach developed to support simulation projects through a framework, stakeholder-oriented tools, and manuals in facilitated workshops. This tutorial describes the PartiSim approach, available for analysts and simulation modelers to use. A PartiSim study includes six stages, four of which involve facilitated workshops. PartiSim has been developed and tested through working with health care organizations. It can, however, be applied to analyze operational problems in any other context within the services and manufacturing domains. This tutorial introduces PartiSim by describing the PartiSim framework and tools, some applications and example tools, a roadmap to adopting it and concludes with some tips for potential users.

LOGISTICS, SCM, TRANSPORTATION / R21

Sea and Ports
Anna Syberfeldt (University of Skövde)

A Decision Support Tool for Port Planning Based on Monte Carlo Simulation / Mª Izaskun Benedicto and Rafael M. García Morales (Proes Consultores, SA); Javier Marino (FCC Industrial); and Francisco de los Santos (Algeciras Port Authority)

Port planning and management has become a difficult task due to the increasing number of elements involved in port operations, their nature (random in some cases), and the relationships between them. Generally, traditional methods involving empirical formulas or queuing theory can be useful though only for simple cases. In the case of complex systems, the problem needs to be approached from a holistic point of view, and more advanced methodologies should be considered. In such cases, simulation may be the most appropriate solution, especially nowadays, when computation and data management are increasingly more efficient. A methodology for port planning and management, based on Monte Carlo simulation, is presented in this paper. A new software application, OptiPort, has been developed based on this methodology, proposed

for use by port managers and planners. The methodology and the software have been validated with real data from the Port of Algeciras.

Challenges and Opportunities in Integration of Simulation and Optimization in Maritime Logistics / Chenhao Zhou, Haobin Li, Weizhi Liu, Aloisius Stephen, Loo Hay Lee, and Ek Peng Chew (National University of Singapore)

Maritime logistics plays an important role in the global trading scene with over 80% of global trade by volume and more than 70% of the trade value being handled by vessels and seaports worldwide. Today, the maritime industry is facing both new challenges and opportunities. Amongst the existing review papers, an in-depth and systematic summary on the integration of simulation and optimization is lacking. To fill the gap, this paper reviews dozens of papers on the integration of simulation and optimization for maritime logistics since 2010. Five modes of integration are classified according to how the two techniques interact with each other. Lastly, the paper introduces new challenges and opportunities in the maritime industry, and how the integration of simulation and optimization can help to boost the development of the next generation maritime systems.

Design and Implementation of Decision Support for Traffic Management at Multipurpose Port Gates / Ketki Kulkarni, Hoong Chuin Lau, Hai Wang, and Sathyavarathan Sivabalasingam (Singapore Management University) and Khiem Trong Tran (Wego Ltd)

Effective traffic management can help port operators gain a competitive edge in service level and efficient use of limited resources. One critical aspect of traffic management is gate operations management, ensuring a good customer experience to logistic carriers and considering the impact of congestion in and around the port. In this paper, we describe the design and implementation of a decision support tool to help gate operators plan for future scenarios with fluctuating demand and limited resources. We propose a simulation-optimization framework which incorporates theoretical results from queuing theory to approximate complex multi-lane multi-server systems. Our major contribution in this paper is the demonstration that the proposed design, when coupled with real data, can indeed help port operators improve their performances. To provide concrete real-world evidence that such technology has benefits, we have tested the system operationally since December 2017 and present the results and analysis in this paper.

MASM / R14

Supply Chain Modeling - I
Hans Ehm (Infineon Technologies AG)

Improving Business Process in Semiconductor Manufacturing by Discovering Business Rules / Abdelhak Khemiri, Maamar El Amine Hamri, and Claudia Frydman (Aix Marseille Université) and Jacques Pinaton (STMicroelectronics)

Process and data are equally important for business process management. Data is especially relevant in the context of automated business processes, and process controlling. In the context of knowledge-intensive domain, data modified by engineers and used by a fully automatic manufacturing system can lead to unpredictable errors. In this paper, a method permitting the discovery of truly enforced business rules used by the process is proposed. These rules will be highlighted using data from the model of the studied process. The proposed methodology is mainly based on a data mining approach. The proposed method has been tested on data from semiconductor industry, in which processes are known to be complex, and the number of business rules is known to be important. The results show that the method is efficient in assisting engineers in process errors detection and practical process improvement.

A Generic VMI Measurement and Application in the Semiconductor Industry / Hans Ehm, Veronika Filser, Frederic Jankowiak, and Tim Lauer (Infineon Technologies AG) and Anh Nguyen (Hogeschool van Arnhem en Nijmegen)

Vendor managed inventory (VMI) is a widespread supply chain collaboration model. To avoid product shortage and excessive stocks, various measurement approaches defining minimum and maximum inventory levels have been designed. None of the known approaches take up the aspect of responsibility regarding the status of the inventory levels. This is especially important in industries facing long process times, short product life cycles and volatile demand patterns, such as the semiconductor industry and their downstream customers. Within this work, a VMI classification checklist is established to build a basis for a common understanding of this collaboration model. This is followed by a generic

VMI measurement approach including a process to assign responsibilities for poor performance. The novel process distinguishes from other measures, as it is of a bilateral nature and parameters can be fitted uniquely to the needs of different VMI partnerships.

Bridging the Gap between Fab Simulation and Supply Chain Forecast / Wolfgang Scholl and Matthias Förster (Infineon Technologies Dresden GmbH), Patrick Preuss and André Naumann (D-SIMLAB Technologies GmbH), and Hui Ping Ooi and Boon Ping Gan (D-SIMLAB Technologies Pte Ltd)

The Infineon Dresden 300mm fab is the first wafer fab in the world to run high volume production of power technology products. This requires the coordination of multiple production facilities in the supply chain. Output from one facility is fed as an input to the subsequent facilities in a push or pull operation mode, depending on technology lines. In a push operation mode, lots transition from one facility to another in a continuous manner, while in the pull operation mode, lots are stored and continuation of the lots is triggered by customer order to the supply chain. The latter case triggers the need of synchronizing material flows from one facility to another, and thus requiring an accurate material forecast for better planning and execution. In this paper, we discuss the modelling issues and solutions associated with this challenge, and the use cases of the simulation forecast.

MILITARY APPLICATIONS / R17

Systems Simulation and Mission Support
Douglas Hodson (AFIT/ENG); Jeremy Millar (AFIT)

Systems Engineering and Simulation: Converging Toward Noble Causes / Bernard Zeigler (RTSync Corp) and Joseph Marvin and John Cadigan (Prime Solutions Group, Inc.)

This paper highlights the accomplishments and shared vision between the International Council on Systems Engineering (INCOSE) and the Modeling and Simulation community (represented by the Society for Modeling and Simulation, International (SCS), and Simulation Interoperability Standards Organization (SISO, among others). We describe convergence between the model-based systems engineering initiative of the INCOSE community and the model-based simulation developments of the SCS community. The goal is not only to highlight the outstanding accomplishments of our time, but also to emphasize the parallels and relationships. The paper is intended to enhance communications and facilitate the outreach already in motion. Modeling and Simulation (M&S) represents a core capability and need for addressing today's complex and grand challenges. We suggest a collaboration of INCOSE and SCS, as leaders in the systems and M&S communities, to solve these challenges complicated by multi-dimensional, hierarchical, and uncertain Big Data and propelled by exascale computational platforms.

A Stochastic Programming Approach to Optimal Recruitment in Australian Naval Aviation Training / Cameron Christopher Charles Pike (Defence Science and Technology Group); Bill Moran, David Kirszenblat, and Brendan Hill (University of Melbourne); and Ana Novak (Defence Science and Technology Group)

We tackle some of the challenges of optimal recruitment strategies of pilots and other aircrew for Royal Australian Navy aviation. Aside from financial costs, too many students in the training system can create bottlenecks and harm morale, while too few poses a risk to delivering operational capability. We propose a stochastic programming approach that can determine the minimum number of students to recruit and how to distribute those students amongst the training system, in order to meet a capability target with a prescribed probability. This approach is parallelizable and reasonably computationally efficient, and utilizes multiple randomized trials of a greedy method to seek a global minimum. Our work provides insights into the relationship between minimization of entry recruitment numbers and minimization of total student numbers in the system, as well as the relationship between risk constraints and convergence to local minima.

Computer Experimentation and Scenario Methodologies to Support Integration and Operations Phases of Mission Engineering and Analysis / Alejandro S. Hernandez, William D. Hatch, Anthony G. Pollman, and Stephen C. Upton (Naval Postgraduate School)

Mission engineering is a recently proposed concept that needs practicable means to implement. Integrating a new system into technical and organizational architectures is a critical part of this initiative. Additionally, it requires an in-depth understanding of the system's operational employment. This paper describes the development of the integration and operations support system, an innovative use of scenario methodologies, computer simulation, and experimentation to shape a strategic analysis framework for mission engineering. A scenario from an actual computer aided exercise, Cobra Gold 2018, is the backdrop of the support system. The Joint Theater Level Simulation drives the operational vignettes for the training audience in this multinational exercise. Our approach is to automate the exercise, thereby creating an experimentation environment for a knowledgeable team to form credible, analytically derived insights about a new system. We generalize this approach and provide a use-case via a planned study on future naval capabilities.

MODELING METHODOLOGY / R26

Arrival Modeling

Andreas Tolk (MITRE Corporation, The MITRE Corporation)

Modeling Bursts in the Arrival Process to an Emergency Call Center / Pierre L'Ecuyer (University of Montreal; DIRO, GERAD, CIRRELT) and Klas Gustavsson and Leif Olsson (Mid-Sweden University, Faculty of Science)

In emergency call centers (for police, firemen, ambulances) a single event can sometimes trigger many incoming calls in a short period of time. Several people may call to report the same fire or the same accident, for example. Such a sudden burst of incoming traffic can have a significant impact on the responsiveness of the call center for other events in the same period of time. We examine data from the SOS Alarm center in Sweden. We also build a stochastic model for the bursts. We show how to estimate the model parameters for each burst by maximum likelihood, how to model the multivariate distribution of those parameters using copulas, and how to simulate the burst process from this model. In our model, certain events trigger an arrival process of calls with a random time-varying rate over a finite period of time of random length.

Resource Scheduling in Non-stationary Service Systems / Samira Shirzaei and Jeffrey Smith (Auburn University)

We focus on a service system in which the customer arrivals are non-stationary and our goal is to determine a server staffing schedule that ensures that arriving customers do not experience long and/or unpredictable queue times. An airport ticket counter is an example of such a system. Passengers arrivals are nonstationary, yet arriving passengers do not wish to wait in long lines to check into their flights. Moreover, unpredictability is a significant issue in these environments as it often forces passengers to arrive earlier than necessary "just in case." Unfortunately, we rarely know the precise form of the arrival process and must use observed samples to set the staffing policy. We show through a case study that simulation combined with a specialized input analysis tool can be used to determine good staffing policies in these environments.

Simulating Residential Energy Demand in Urban and Rural Areas / Swapna Thorve, Samarth Swarup, Achla Marathe, Youngyun Chungbaek, Eric K. Nordberg, and Madhav V. Marathe (Virginia Tech)

Residential energy demand dynamics at household level can be studied through demographic, behavioral and physical characteristics of the household. In this paper, we develop an agent-based model using a bottom-up approach to build disaggregated energy demand estimates at the household level at an hourly interval. A household level analysis is made possible via the use of synthetic populations for the urban and rural areas of Virginia, USA. The energy consumption estimate is based on householders' demographics, their behaviors, and activities, ratings of appliances used in energy-related activities, space conditioning fuels, physical characteristics of the home, and weather conditions. Results from the simulation are then validated with actual demand curves from Rappahannock county in Virginia using dynamic time warping. The simulation results show that the model produces realistic energy demand profiles.

PROJECT MANAGEMENT AND CONSTRUCTION / R24

Smart Buildings / Simulation of Occupant Behavior
Raimar Scherer (Dresden University of Technology, Institute of Construction Informatics)

Exploring the Validity of Occupant Behavior Model for Improving Office Building Energy Simulation / Mengda Jia, Ravi S. Srinivasan, and Robert Ries (University of Florida) and Gnana Bharathy (University of Pennsylvania)

Building energy use is significantly influenced by building occupants or users. The integration of a robust occupant behavior model that captures energy-related behaviors and a building energy model will have the potential to improve energy simulation performance, as current virtual model of building lacks dynamic and practical occupant information input. Agent-based Modeling (ABM) has been successfully applied to model interactions between occupants and building components, but most of the models were developed on a simulation basis without actual data involvement. To address on this issue, this paper proposes an approach to modeling occupant behaviors in office buildings via the design of a novel ABM and relevant data collection for model testing and validation. A case study is conducted to investigate the performance of the model. The results show the applicability of the ABM and provide a feasible direction for tuning ABM for the purpose of building energy simulation improvement.

Towards a Multimodel Approach for Simulation of Crowd Behaviour under Fire and Toxic Gas Expansion in Buildings / Raimar J. Scherer, Ngoc Trung Luu, and Peter Katranuschkov (TU Dresden, Institute of Construction Informatics); Sven Spieckermann and Ilka Habenicht (SimPlan AG); and Byron Protopsaltis and Theodora Pappou (FIDES DV-Partner GmbH)

A holistic approach for the simulation of evacuations from buildings in cases of fire and toxic gas spread is developed within the German project iSiGG to achieve high reliability in fire safety planning. Its essence is in the mutual interaction of the domains of crowd simulation, pollutant gas spread simulation (CFD) and Building Information Modeling (BIM), embedded in a coherent IT system. The conceptual basis of this system is provided by a dynamic multimodel ensuring interoperability of all system components and supplying simulation tasks with the necessary building and environmental data. More importantly, it allows to take into account various possible changes of the state of building elements, which may be caused by inhabitants or by the building control systems and can lead to strong changes in the simulation models. The simulations themselves are coupled on numerical level through a shared Voxel Model in a co-simulation approach.

A Zoning Framework for Enhanced Smart Building Automation / Sanja Lazarova-Molnar (University of Southern Denmark), Nader Mohamed (Middleware Technologies Lab.), and Elena Markoska (University of Southern Denmark)

Smart buildings are complex cyber-physical systems that typically involve a high degree of human interaction. This interaction, if controlled and utilized adequately, can provide a significant hint in fine-tuning and optimizing systems, as well as in diagnosing problems in systems in a timely manner. In this paper we define a Zoning Framework for enhanced and, potentially, optimal automation of buildings that utilizes the potential of human interaction and its multifaceted nature in optimizing on the various performance metrics of buildings. We, furthermore, present a workflow in which the framework can be utilized to optimize data collection processes, and, thus, aid in meeting performance goals of smart buildings.

SIMULATION FOR A NOBLE CAUSE / R22

Healthcare
George Miller (MOSIMTEC)

Optimal Enterprise Results in the Clinical Research Environment / Antonio R. Rodriguez (National Institutes of Health (NIH))

Even the best scientific minds cannot repeatedly produce desired results when working in sub-optimal systems. Complex enterprises are difficult to understand and manage. Cause-and-effect relationships are often separated in time and space, making real improvements challenging. To understand how complex systems work it is essential that we employ tools that accurately map and quantify the dynamics that drive results. Computer modeling and simulation (CMAS) is a

valuable design, planning, management, and overall analytical decision-support tool to achieve effective and efficient results. CMAS could become a ubiquitous tool in the lengthy and complex environment of the clinical research (CR) enterprise. Without the comprehensive understanding gained when applying CMAS, organizations may continue to be overwhelmed by problems such as unnecessary bottlenecks, high costs, low productivity, and the inability of retaining critical staff. The approach explained here may complement or even replace traditional methods when organizations pursue greater enterprise capability.

An Integrated Simulation Framework for Examining Resiliency in Pharmaceutical Supply Chains Considering Human Behaviors / Rozhin Doroudi, Rana Azghandi, Zlatan Feric, Omid Mohaddesi, Yifan Sun, Jacqueline Griffin, Ozlem Ergun, David Kaeli, Pedro Sequeira, Stacy Marsella, and Casper Harteveld (Northeastern University)

The growing epidemic of drug shortages in the United States causes challenges for providers all across the critical health care infrastructure and demonstrates the lack of resiliency within drug delivery supply chains. With many drugs having no acceptable substitute, drug shortages directly translate to a public health and safety risk. One of the understudied elements driving this crisis is the role of human behavior and human decision making across the supply chain echelons. We propose an integrated simulation framework which allows for instantiating, testing, and improving supply chains when accounting for human components of the system. We demonstrate the potential insights that can be obtained with our method through several experiments in which supply chain decision makers account for how others might react to their decisions.

RH-RT: A Data Analytics Framework for Reducing Wait Time at Emergency Departments and Centres for Urgent Care / Navonil Mustafee, John Powell, and Alison Harper (University of Exeter)

Right Hospital – Right Time (RH-RT) is the conceptualization of the use of descriptive, predictive and prescriptive analytics with real-time data from Accident & Emergency (A&E)/Emergency Departments (ED) and centers for urgent care; its objective is to derive maximum value from wait time data by using data analytics techniques, and making them available to both patients and healthcare organizations. The paper presents an architecture for the implementation of RH-RT that is specific to the authors' current work on a digital platform (NHSquicker) that makes available live waiting time from multiple centers of urgent care (e.g., A&E/ED, Minor Injury Units) in Devon and Cornwall. The focus of the paper is on the development of a Hybrid Systems Model (HSM) comprising of healthcare business intelligence, forecasting techniques and computer simulation. The contribution of the work is the conceptual RH-RT framework and its implementation architecture that relies on near real-time data from NHSquicker.

SIMULATION OPTIMIZATION / J2

New Methods for Efficient SO
Jeff Hong (City University of Hong Kong)

Plausible Optima / Matthew Plumlee and Barry L. Nelson (Northwestern University)

We propose a framework and specific algorithms for screening a large (perhaps countably infinite) space of feasible solutions to generate a subset containing the optimal solution with high confidence. We attain this goal even when only a small fraction of the feasible solutions are simulated. To accomplish it we exploit structural information about the space of functions within which the true objective function lies, and then assesses how compatible optimality is for each feasible solution with respect to the observed simulation outputs and the assumed function space. The result is a set of plausible optima. This approach can be viewed as a way to avoid slow simulation by leveraging fast optimization. Explicit formulations of the general approach are provided when the space of functions is either Lipschitz or convex. We establish both small- and large-sample properties of the approach, and provide two numerical examples.

On Parallelizing Multi-Task Bayesian Optimization / Matthew Groves, Michael Pearce, and Juergen Branke (University of Warwick)

Parallelizing Bayesian Optimization has recently attracted a lot of attention. The challenge is usually to estimate the effect multiple new samples will have on the posterior distribution of the objective function, and the combinatorial

explosion of the possible sample locations. In this paper, we show that at least for multi-task Bayesian Optimization, parallelization is straightforward because the benefit of samples is independent as long as they are sufficiently far apart in the task space. We propose a simple penalization approach proportional to correlation based on the kernel and demonstrate that for the problem settings we considered, the efficacy of our parallel multi-task Bayesian Optimization algorithm is close to the sequential version, while being able to exploit parallel computation to speed up optimization. Depending on the setup considered, we observe efficiencies of parallelization between 69% and 100%.

Gaussian Mixture Model-based Random Search for Continuous Optimization via Simulation / Wenjie Sun and Zhaolin Hu (Tongji University) and Jeff Hong (City University of Hong Kong)

This paper studies integrated random search algorithms for continuous optimization-via-simulation (COvS) problems. We first tailor the Gaussian process-based search (GPS) algorithm to handle COvS problems. We then analyze the potential sampling issue of the GPS algorithm and propose to construct a desirable Gaussian mixture model (GMM) which is amenable for efficient sampling and at the same time also maintains the desirable property of exploitation and exploration trade-off. Then, we propose a Gaussian mixture model-based random search (GMRS) algorithm. We build global convergence of both the tailored GPS algorithm and the GMRS algorithm for COvS problems. Finally, we carry out some numerical studies to illustrate the performance of the GMRS algorithm.

SIMULATION STANDARDS AND REPRODUCIBILITY / R15

Panel: Reproducibility in Modeling & Simulation
Simon J. E. Taylor (Brunel University London)

Crisis, What Crisis – Does Reproducibility in Modeling & Simulation Really Matter? / Simon JE Taylor and Tillal Eldabi (Brunel University London), Thomas Monks (University of Southampton), Markus Rabe (Technical University of Dortmund), and Adelinde M. Uhrmacher (University of Rostock)

How important it is to our discipline that we can reproduce the results of Modeling & Simulation (M&S) research? How important is it to be able to (re)use the models, data, and methods described in simulation publications to reproduce published results? Is it really that important or are the lessons and experiences described in a paper enough for us to build on the work of others? At the 2016 Winter Simulation Conference, a panel considered opinions on reproducibility in discrete-event simulation. This article builds on these and asks if there really is a reproducibility crisis in M&S? A diverse range of views on the subject are presented including reflections on the reproducibility in terms of the art and science of simulation, the frustrations of poor reproducibility, perspectives from the industrial production & logistics community, the wider context of open science and artefact sharing, and the role of provenance beyond reproducibility.

VENDOR TUTORIALS / R25

ExtendSim / Siemens PLM

Vehicles on Networks in Discrete Event Simulation / Guillaume Lagaillarde (1POINT2)

It is no mystery that mobility is one of the challenges society and industry have to face. Mobility is not only a issue for people. It is also a necessity for goods and any piece of material inside and outside factories. Without movement, no production. One of the most flexible way to move people or goods from one place to another is using Vehicles moving on networks. Sometimes the vehicle is just a human transporting an object. Yet, this essential function : calling a vehicle located in C to transport an object from A to B on a navigation network (often shared with other vehicles you don't want to collide) is not always present out of the box in standard discrete event simulation packages. ExtendSim, a great, affordable and flexible simulation toolbox is a good platform to develop such fundamental function. 1Point2 present its generic Vehicle on network ExtendSim library.

The Digital Twins of Product, Production and Performance / Johan Nordling and Gunnar Latz (Siemens PLM Software)

Siemens is a leading global provider of software solutions to drive the digital transformation of industry, creating new opportunities for manufacturers to

realize innovation. This session will focus on two of our simulation solutions and we will mix product updates with industrial use-cases: Simcenter Amesim, that allows system simulation engineers to virtually assess and optimize the performance of mechatronic systems; and Plant Simulation, that allows users to model, simulate, explore and optimize logistics systems and their processes.

Monday 5:30p.m.-6:30p.m.

JOINT SESSION: POSTER & PHD COLLOQUIUM / CONGRESS FOYER

PhD Colloquium and Poster Session

Tuesday 8:00a.m.-9:30a.m.

ADVANCED TUTORIALS / R23

Stochastic Gradient Descent
Giulia Pedrielli (Arizona State University)

Recent Trends in Stochastic Gradient Descent for Machine Learning and Big Data / David Newton and Raghu Pasupathy (Purdue University) and Farzad Yousefian (Oklahoma State University)

Stochastic Gradient Descent (SGD), also known as stochastic approximation, refers to certain simple iterative structures used for solving stochastic optimization and root finding problems. The identifying feature of SGD is that, much like in gradient descent for deterministic optimization, each successive iterate in the recursion is determined by adding an appropriately scaled gradient estimate to the prior iterate. Owing to several factors, SGD has become the leading method to solve optimization problems arising within large-scale machine learning and "big data" contexts such as classification and regression. This tutorial covers the basics of SGD with an emphasis on modern developments. The tutorial starts with examples where SGD is applicable, and then details important flavors of SGD and reported complexity calculations.

AGENT-BASED SIMULATION / R5

Transportation
Casey Bowman (University of North Georgia)

Incremental Calibration of Seat Selection Preferences in Agent-based Simulations of Public Transport Scenarios / Philipp Andelfinger (TUMCREATE Ltd and Nanyang Technological University), Daniel Zehe (TUMCREATE Ltd), Chen Yihao and Boyi Su (TUMCREATE Ltd and Nanyang Technological University), David Eckhoff (TUMCREATE Ltd and Technical University Munich), Wentong Cai (Nanyang Technological University), and Alois Knoll (Technical University of Munich)

The calibration of agent-based pedestrian simulation models requires empirical data. To avoid cost-intensive real-world experiments, human-in-the-loop simulations can be applied in which simulated pedestrians interact with human-controlled agents. However, the experiment results may be unrealistic if the human participants are presented with agents acting according to an uncalibrated model. We propose an incremental calibration approach that aims to address the circular dependency between the behaviour of human and simulated pedestrians. By incrementally adapting the parameters of the simulated agents to match the behaviour of the human participants, we aim to gradually approach a realistic interaction. We evaluate our approach using the simulation of the boarding procedure of a public transport vehicle in 2D and virtual reality experiments. The calibration results are compared with those gathered from a traditional non-incremental calibration. Our results indicate the feasibility of our approach and highlight the necessity for future research on efficient simulation model calibration.

Toward Understanding the Impact of User Participation in Autonomous Ridesharing Systems / Wen Shen, Rohan Achar, and Cristina V. Lopes (University of California, Irvine)

Autonomous ridesharing systems (ARS) promise many societal and environmental benefits, including decreased accident rates, reduced energy consumption and pollutant emissions, and diminished land use for parking. To unleash ARS' potential, stakeholders must understand how the degree of passenger participation influences the ridesharing systems' efficiency. To date, however, a careful study that quantifies the impact of user participation on ARS' performance is missing. Here, we present the first simulation analysis to investigate how and to what extent user participation affects the efficiency of ARS. We demonstrate how specific configurations (e.g., fleet size, vehicle capacity, and the maximum waiting time) of a system can be identified to counter the performance loss due to users' uncoordinated behavior on ridesharing participation. Our results indicate that stakeholders of ARS should base decisions regarding system configurations on insights from data-driven simulations and make tradeoffs between system efficiency and price of anarchy for desired outcomes.

Smart City Real-Time Data-Driven Transportation Simulation / Abhilasha Saroj, Somdut Roy, Richard Fujimoto, Angshuman Guin, and Michael Hunter (Georgia Institute of Technology)

This study assesses feasibility aspects of using a real-time data-driven transportation simulation model to evaluate and visualize network performance indices to provide dynamic operational feedback in a real world environment, in a big data context. A hybrid traffic simulation model, consisting of a mix of preset and real-time data-driven intersections, is developed. The hybrid model represents a traffic corridor partially equipped with smart devices generating high velocity, high volume datasets with limited shelf-life. The model used in this study emulates seventeen consecutive intersections on a corridor. Signal controls and vehicle volumes at two of the intersections are driven by real-time data while the remaining intersections are driven by preset data. An optimized architecture is developed to enable control of the signals and the vehicle volumes using real-time data from in-field detectors, and real-time processing of the vehicle trajectories from the simulation output to generate travel-time, energy, and emissions performance indices.

ANALYSIS METHODOLOGY / CONGRESS HALL

Statistical Innovations

Eunhye Song (Penn State University)

Simulation of Bipartite or Directed Graphs with Prescribed Degree Sequences Using Maximum Entropy Probabilities / Paul Glasserman and Enrique Lelo de Larrea (Columbia University)

We propose an algorithm for simulating bipartite or directed graphs with given degree sequences, motivated by the study of financial networks with partial information. Our algorithm sequentially computes certain "maximum entropy" matrices, and uses the entries of these matrices to assign probabilities to edges between nodes. We prove the correctness of the algorithm, showing that it always returns a valid graph and that it generates all valid graphs with positive probability. We illustrate the algorithm in an example of an inter-bank network.

Multiply Reflected Variance Estimators for Simulation / Kemal Dingec (Altinbas University), Christos Alexopoulos and Dave Goldsman (Georgia Institute of Technology), Melike Meterelliyoz (TOBB University), and James Wilson (North Carolina State University)

In a previous article, we studied a then-new class of standardized time series (STS) estimators for the asymptotic variance parameter of a stationary simulation output process. Those estimators invoke the well-known reflection principle of Brownian motion on the suitably standardized original output process to compute several "reflected" realizations of the STS, each of which is based on a single reflection point. We then calculated variance- and mean-squared-error-optimal linear combinations of the estimators formed from the singly reflected realizations. The current paper repeats the exercise except that we now examine the efficacy of employing multiple reflection points on each reflected realization of the STS. This scheme provides additional flexibility that can be exploited to produce estimators that are superior to their single-reflection-point predecessors with respect to mean-squared error. We illustrate the enhanced performance of the multiply reflected estimators via exact calculations and Monte Carlo experiments.

European Option Pricing With Stochastic Volatility And Jumps: Comparison of Monte Carlo and Fast Fourier Transform Methods / Uro C. Lyi (Montgomery Blair High School Math, Science, and Computer Science Magnet Program) and Michael C. Fu (University of Maryland, College Park)

In this paper, European option prices are computed analytically, as well as simulated, for underlying asset price models with stochastic volatility and jump discontinuities. The analytical price is derived using the Fast Fourier Transform method developed in previous literature, which enables prices to be computed quickly. This model is compared with the Black-Scholes model, and the results suggest that this model addresses a known issue with the Black-Scholes model, the under and over valuations of short maturity options. The analytical solution is also used to investigate effective control variates in Monte Carlo simulations. Simulation experiments indicate that the random motion of the asset price serves as an effective control variate.

JOINT SESSION: CYBER-PHYSICAL SYSTEMS & AVIATION MODELING AND ANALYSIS / R11

CPS for Transportation Sector
Miguel Mujica Mota (Amsterdam University of applied Sciences, Amsterdam University of Applied Sciences)

Modelling the Automatic Deployment of Oil-spill Booms: A Simulation Scenario for Sea Cleaning / Juan Jiménez and José María Girón Sierra (Complutense University of Madrid)

Booms are extensively used for confining oil spilled at sea and for carrying it away from sensitive areas or toward a gathering point. The success of booming operations depends on effective boom deployment, which, in turn, is conditioned by the state of the sea – wind, tides, currents, and waves – and its effects on the spill spreading shape and speed. Planning the boom deployment beforehand could help overcome problems derived from sea condition. Besides, the employment of Unmanned Surface Vehicles (USVs) for towing spill recovery booms represents an interesting alternative to the use of ordinary vessels, and it could lead to a fully automatic oil spill recovery system. A basic tool has been developed in Python to simulate the deployment of booms towed by USVs. The aim is to explore simple trial scenarios, working out information that helps to prototype real USV-boom systems and to plan automatic deployments.

Multi-Sensor Fault Detection and Isolation for Aero-Engine DCS With Markov Time Delay Based on H_∞ Unknown Input Observers / Ledi Zhang, Shousheng Xie, Yu Zhang, and Litong Ren (Air force engineering university)

In this paper, a novel approach is proposed to design a bank of unknown input observers(UIOs) for aero-engine distribute control system(DCS) with multi-sensor fault. First, considering the system with multi-sensor fault which doesn't satisfy the observer matching condition, a H_∞ UIO is proposed based on the disturbance decoupling principle of unknown input observer(UIO) and H_∞ control theory. The parameter matrixes of UIO are solved in terms of linear matrix inequality(LMI) toolbox. Second, the fault detection and isolation scheme is proposed for DCS with multi-sensor fault and the UIOs are designed for a bank of fault detection and isolation sets which are obtained by reorganizing the control system. The residual signal generated by each observer is robust to the sensor fault in the matching set, and sensitive to the sensor fault out of the matching set. Finally, the residual signals were simulated and the results show the effectiveness of the proposed method.

Learning from Historical Data to Predict Electric Vehicle Taxi Consumption and Charging Time / Kim Rioux-Paradis, Jonathan Gaudreault, Chloé Redmond, Kento Otomo-Lauzon, Frédéric Bernard, Anthony Deschenes, and Claude-Guy Quimper (Université Laval); Simon Boivin (TEO Taxi); and Pascal Blouin (Institut du Véhicule Innovant)

Electric taxi fleet simulation calls for a lot of uneasily accessible data. We learned from historical data in order to predict electric vehicle consumption and charging time. Although simulation was the main goal, the developed models will be used by the dispatching team of the company. Moreover, the data analysis process allowed us to discover flaws in the infrastructure (e.g., defective stations and defective batteries).

CASE STUDIES / R4

Homeland Security / Emergency Response
Ilka Habenicht (SimPlan AG)

Simulation of Flood Evacuation Operations in Pierrefonds, Montréal / Neelghosh Muthalakattil, Ruo Liang, Harsh Shah, Maryam Hemmati, Melvin Kurien, and Daria Terekhov (Concordia University)

This study focuses on simulating the evacuation of a neighborhood of Montréal, Québec, Canada in the event of flooding. Two strategies are simulated, and it is concluded that a significant reduction in the average evacuation time per family can be obtained by appropriate scheduling of the evacuation buses.

Using Simulation to Advance Realism in Law Enforcement Training / Brian Dorow (DHS)

Training instructors are using advanced, interactive use-of-force simulators to produce unique training experiences for law enforcement officers. While today's simulators are sophisticated with scenarios that make them invaluable tools in law enforcement training, much of the training doesn't take full advantage of simulator capabilities when used in the context of a larger training environment. Based on the professional experiences of the author, an immersive concept that would require trainees to not just react to the video on the simulator, but to work the scenario within the context of a larger environment would be extremely beneficial. A training venue has been developed with the goal of revolutionizing law enforcement training in Wisconsin. Using simulation scenario-based learning and training offers many benefits to law enforcement officers and advances realism in law enforcement training.

HEALTHCARE APPLICATIONS / R12

System dynamics in healthcare
Xiaolan Xie (Ecole Nationale Superieure des Mines de Saint-Etienne, France)

Limits of Doing More with Less: A Simulation Study of Facilities Management Work Orders in a Health System / Shivraj Kanungo (The George Washington University) and Nancy Ban (Central Maine Healthcare)

The facilities management department of a U.S. health system has experienced a 42.28% turnover rate within the last year. Despite the human resources team's work to mitigate turnover, insufficient attention has been given to burnout within the department. There is a need to explore alternative frameworks to investigate the issue that take into account the complexities and impact of staff burnout on the health system. This paper starts by developing an understanding of the root causes and behavior of burnout within a department and scrutinizing the complexity of how departmental decisions impact the health system as a whole. This is followed by a simulation model based on the data collected from managers at the health system. We conclude with a discussion of the insights that were derived from both causal loops as well as that from the results of the Vensim simulation. Finally, plans for future work are outlined.

Evaluating Cost-effectiveness of Treatment Options for Diabetes Patients Using System Dynamics Modeling / Shiyong Liu and Judy C. Xu (Southwestern University of Finance and Economics), Gordon Liu (Peking University), David Bishai (Johns Hopkins University), Hong Xue (Virginia Commonwealth University), and Youfa Wang Wang (Ball State University)

The growing global diabetes epidemic is a serious public health problem. We developed a system dynamic model to study the cost-effectiveness of different diabetes treatment options. According to existing literature, we estimated dynamic costs and changes of hemoglobin A1c levels of two first-line monotherapies and a hypothetical innovation therapy for glycemic control over a 15-year horizon. Incremental cost-effectiveness ratios were expressed as dollars per HbA1c decrement from perspectives of the patient, insurance-payer, and society. Simulation results showed that better adherence with a more expensive and efficacious drug results in better control of HbA1c and cost-saving in the long-run. The results also showed that the cost-effectiveness ratio varied with patients' pre-determined out-of-pocket payment for health expenditure. The higher the rate of their out-of-pocket payment for extra health care expenditure to their household income, the more cost-effective it is for the innovative drug from the perspectives of the patient, insurance-payer, and society.

HYBRID SIMULATION / R6

Hybrid Simulation Frameworks
Navonil Mustafee (University of Exeter)

Application of Hybrid Simulation Modelling for the Implementation of Job Rotation in a Feedmill / Omogbai Oleghe and Konstantinos Salonitis (Cranfield University)

This paper promotes a unique system dynamics-discrete event simulation hybrid modelling framework. The way the hybrid model is developed is intended to simplify the modelling process and make the framework flexible to a variety of situations. In the current study, the framework is used to investigate the success possibility of introducing within-shift job rotation in the plant and its optimal

frequency. The intention is to reduce worker exhaustion and by so doing increase productivity and manufacturing throughput. The improvement decisions generated from the simulation results could not have been achieved using any other means. The hybrid modelling framework presents a coherent, straightforward standardized approach that includes the main tasks in SD-DES hybrid modelling. A recommendation for future research is to test the framework's adaptability to a variety of settings.

Framework for a Hybrid Simulation Approach for an Integrated Decision Support System in Healthcare Facilities / Jennifer I. Lather and John I. Messner (The Pennsylvania State University)

There is a lack of integration of facility planning techniques in the design and layout of healthcare facilities. Computational models can be used to evaluate minimal distances or cost functions. Discrete event simulations can be used to model the stochastic nature of operations to check the impact on specific performance measures. Visualization can be used to immerse decision makers in the future environment to aid model validity, communication, and understanding. In this paper, we discuss three techniques: mathematical optimization, discrete event simulation, and virtual visualization, and present a framework for using them in an integrated hybrid simulation modeling approach in the healthcare planning process. We present objectives for the use of these techniques throughout the lifecycle in one unit of a healthcare facility. These techniques, while described in a healthcare context, have implications for other domains where uncertain and latent processes are components of the layout decision making process.

DDDAS Advantages from High-dimensional Simulation / Erik Blasch (Air Force Office of Scientifc Research (AFOSR))

Dynamic Data Driven Applications Systems (DDDAS) is a systems design framework that focuses on integrating high-dimensional physical model simulations, run-time measurements, statistical methods, and computation architectures. One of the foremost DDDAS successes was scientific theory assessment of natural disasters such as wild fire monitoring and volcanic plume detection. Monitoring the atmosphere with DDDAS principles has evolved into domain methods for space awareness, unmanned aerial vehicle (UAV) design, and biomedical applications. Recent efforts reflect the digital age of information management architecture design such as multimedia analysis, power grid control, and biohealth concerns. Underlying a majority of DDDAS developments are advances in sensor design, information filtering, and computational systems. The paper provides a motivation, explanation, and literature review of DDDAS.

INTRODUCTORY TUTORIALS / R31

Tutorial on Agent-based Modeling and Simulation
Beatriz Beyer (University of Göttingen)

Tutorial on Agent-based Modeling and Simulation: ABM Design for the Zombie Apocalypse / Charles Macal (Argonne National Laboratory)

Agent-based modeling (ABM) and simulation is an approach to modeling systems comprised of autonomous, interacting agents. Computational advances are making it possible to develop agent-based models in a variety of application areas, including areas where simulation has not been extensively applied. ABM applications range from supply chains, consumer goods markets, and financial markets, to predicting the spread of epidemics and understanding the factors responsible for the fall of ancient civilizations. Progress suggests that ABM could have far-reaching effects on the way that businesses use computer models to support decision-making and how researchers use models as electronic laboratories to identify promising research directions. Some contend that ABM "is a third way of doing science" and could augment traditional discovery methods for creating new knowledge. This brief tutorial introduces agent-based modeling by describing key concepts of ABM and addressing toolkits and methods for developing agent-based models.

LOGISTICS, SCM, TRANSPORTATION / R21

Simulation of Transport Logistics Facilities and Systems
Marc Kirberg (TU Dortmund University)

How Order Placement Influences Resource Allocation and Order Processing Times Inside a Multi-User Warehouse / Ralf Elbert and Jan-Karl Knigge (Technische Universität Darmstadt)

This paper focuses on the influence of different order placement behavior of users on the allocation of common resources inside a multi-user warehouse. Furthermore, the interdependencies between one user's resource usage on other users' order processing time is investigated. For this objective, an agent-based simulation model has been developed, depicting a rectangular warehouse with two users and one order picker. Results show that different order placement behavior and resource usage of one user have a strong influence on order processing times of other users. Furthermore, by simulating uneven order placement by one user, it can be shown that peaks in order demand influence other user's order processing times with a delay of up to two hours after the peak occurred. Thus, the results highlight the need for coordinated order placement of partners inside a multi-user warehouse.

Physx as a Middleware for Dynamic Simulations in the Container Loading Problem / Juan Camilo Martínez-Franco and David Álvarez-Martínez (Universidad de Los Andes)

The Container Loading Problem (CLP) is an optimization challenge where the constraint of dynamic stability plays a significant role. The evaluation of dynamic stability requires the use of dynamic simulations that are carried out either with dedicated simulation software that produces very small errors at the expense of simulation speed, or real-time physics engines that complete simulations in a very short time at the cost of repeatability. One such engine, PhysX, is evaluated to determine the feasibility of its integration with the open source application PackageCargo. A simulation tool based on PhysX is proposed and compared with the dynamic simulation environment of Autodesk Inventor to verify its reliability. The simulation tool presents a dynamically accurate representation of the physical phenomena experienced by cargo during transportation, making it a viable option for the evaluation of dynamic stability in solutions to the CLP.

A Simulation Model for the Planning and Control of AGVs at Automated Container Terminals / Berry Gerrits, Martijn Mes, and Peter Schuur (University of Twente)

This paper presents a scalable and flexible agent-based simulation (ABS) model for the planning and control of AGVs at automated container terminals (ACTs). A comprehensive and generic multi-agent system is presented to effectively manage the container handling process between the quay and stacks of ACTs. Specifically, we design an agent-based Traffic Manager, which serves as a control application layer for all processes related to the horizontal transport of containers using AGVs. Our ABS model provides a playground to easily test out the effectiveness of different types and layouts of ACTs.

MANUFACTURING APPLICATIONS / R2

Continuous Improvement of Processes
Camilla Lundgren (Chalmers University of Technology)

Workpiece Positioning Based on Supervised Learning Methods for Simulation-based Optimization of Virtual Tooling Processes / Jens Weber and Sebastian Risse (Daimler AG) and Christoph Laroque (University of Applied Sciences Zwickau)

The setup process, Numerical Control (NC) program configuration and the linked configuration of point of origins, workpiece position, tool ranges require high computational effort that include multiple simulation runs during the work preparation process. This contribution describes an automatic setup optimization process, including validation of position parameters using a virtual tooling machine as simulation model. In the first step, the developed simulation-based optimization approach minimizes the production time while the collision information and NC program validation are provided by the simulation. In the next step, a cluster method is applied to avoid a high number of single simulation runs, but the validation effort is still high. In

order to address this point the developed system offers a selection and data reconciliation procedure using supervised learning methods to determine feasible workpiece positions.

Application of Online Learning for the Dynamic Configuration of Kanban Systems / Daniel Rippel (BIBA - Bremer Institut für Produktion und Logistik GmbH at the University of Bremen), Michael Theß (Signal Cruncher GmbH), Michael Lütjen (BIBA - Bremer Institut für Produktion und Logistik GmbH at the University of Bremen), and Michael Freitag (University of Bremen)

Kanban systems constitute a widely used pull control for inventory management in production systems. As a result of an increasingly volatile and individualized customer demand, Kanban systems have to be reconfigured dynamically to achieve minimal inventory levels while maintaining a stable production. This paper investigates the application of an incremental online learning platform called XELOPRO to optimize inventory levels using the current state of the production system, while including contextual information, e.g., time-related information. As the platform uses an incremental support vector machine to update its models during runtime without the need to store and reevaluate large amounts of historical data, it constitutes a suitable tool for a decentralized inventory management. Results show a good performance with drastic decreases in inventory levels compared to static configurations and a higher reliability compared to a dynamic application of standard Kanban rules.

Methodology for Layout and Intralogistics Redesign Using Simulation / Pawel Pawlewski (Poznan University of Technology)

The paper describes a methodology for layout and intralogistics redesign using simulation. This methodology is composed of five stages: Topography, Product & Process, Linkages, Simulation, and Results. Key foundations are defined as PFEP (Plan for Every Part), Workstation as basic object for simulation, high level script language, cyclic processes, and 3D core simulation. The simulation model is built based on an earlier-prepared AutoCad drawing as background and on data in Excel about the Bill of Materials, PFEP, Container List, Assignment, and Operations. The simulation model is built using the developed template, which significantly shortens the modeling time.

MASM / R14

Production Planning Applications
Reha Uzsoy (North Carolina State University)

Simulation Optimization for Planning Product Transitions in Semiconductor Manufacturing Facilities / Atchyuta Bharadwaj Manda and Reha Uzsoy (North Carolina State University)

The introduction of a new product into a semiconductor manufacturing facility can have significant adverse effects on both current and new products. We combine a simulation model of a simplified production system and a learning model to optimize releases of old and new products using simulation optimization. Our results show that the simulation optimization model yields significant improvements in performance over simple alternatives, and provides insights into the structure of optimal release policies.

An Exploratory Comparison of Clearing Function and Data Driven Production Planning Models / Karthick Gopalswamy and Reha Uzsoy (North Carolina State University)

Production planning models face the fundamental problem of capturing the nonlinear relation between resource workload and cycle times. One approach to this has been the use of nonlinear clearing functions that represent the expected output of a production resource in a planning period as a function of the expected workload in that period. Recently an alternative data driven approach that represents the behavior of the system using a set of system states and their corresponding output levels has been proposed. We compare the clearing function based approach to the data driven approach using a simulation model of a scaled-down semiconductor wafer fabrication facility and discuss the strengths and weaknesses of the two approaches.

Optimizing Starts for Capacity, Velocity, and Output During the Ramp-up Period of a Semiconductor Fab / Adar Kalir and Kosta Rozen (INTEL)

In this paper, we address the question of how to maximize output over the ramp-up period of a semiconductor fab. We postulate that by keeping a margin between the constraint capacity and the ramp starts cumulative output can be increased over a desired planning horizon (e.g. first year of production). A mathematical framework of the problem is offered and then used to prove our hypothesis. We demonstrate the benefit via a numerical example and a set of simulation experiments.

MILITARY APPLICATIONS / R17

Military Modeling and Analysis
Nathaniel Bastian (U.S. Army); Andrew Hall (The Joint Staff)

Optimisation of Naval Gun Firing Patterns for Engagement of Manoeuvring Surface Targets / Peter J. Young (Centre for Operational Research and Analysis, Defence Research and Development Canada)

The problem of determining optimal naval gun firing patterns for engagement of manoeuvring surface targets using traditional simulation approaches is computationally intensive, particularly for large salvo sizes. A simplified modelling technique based on representing warhead effects using Gaussian function approximations calibrated from more detailed modelling is reported here. The simplified model permits the parameter space defining lay-down of rounds in a firing pattern to be searched so as to determine optimal patterns that maximise salvo probability of kill. The method employs Newton's method to formulate a system of equations defining local extrema, which are then solved using Gaussian elimination. These extrema are then searched to obtain the pattern that maximises salvo kill probability. This paper presents the underlying theory and gives initial results obtained using the model calibrated for an illustrative example from a more detailed model.

Combat Simulation Analytics: Regression Analysis, Multiple Comparisons and Ranking Sensitivity / Andrew Gill, Dion Grieger, Martin Wong, and William Chau (Defence Science and Technology Group)

The design and analysis of simulation experiments and the analysis of simulated alternatives are critically important tasks when employing combat simulations in support of Army modernization. Effective sensitivity and ranking analyses enable insight to be gained on the marginal contributions of sub-systems to overall operational effectiveness, as well as comparatively assessing competing system alternatives. This paper makes some unifying discoveries related to sensitivity analysis via linear multiple regression, and discusses some empirical findings concerning ranking analysis via score-based, partition-based and consensus-based methods. Finally, an investigation into the combined ranking sensitivity problem is also attempted.

Optimizing Recruitment to Achieve Operational Capability Conditional on Appetite for Risk / Brendan Hill, David Kirszenblat, and Bill Moran (University of Melbourne, Defence Science and Technology Group) and Ana Novak (Defence Science & Technology Group)

This work is motivated by the need for the Australian Defence Force to produce the right number of trained aircrew in the right place at the right time. This necessitates the development of optimal recruitment strategies while sustaining squadron capability within some risk tolerance. The challenge is that Defence Aircrew training environments typically have highly variable failure rates and relatively small numbers of students. We investigate three receding horizon strategies, each of which use inflated notional targets with some deterministic assumptions to mitigate risk. The first strategy back-fills expected demand given fixed targets; the second strategy dynamically chooses targets using Monte Carlo simulations; and the third strategy incorporates Integer Linear Programming for partial solutions. We show that the first two strategies scale well and maintain steady states, and that the second strategy successfully incorporates the risk tolerance, resulting in an efficient and highly scalable strategy for the recruitment problem.

MODELING METHODOLOGY / R26

Modeling Formalisms - I
Rhys Goldstein (Autodesk Research)

A Conceptual Framework to Classify the Extensions of DEVS Formalism as Variants and Subclasses / María Julia Blas, Silvio Gonnet, and Horacio Leone (Instituto de Diseño y Desarrollo INGAR (UTN-CONICET)) and Bernard Zeigler (University of Arizona, RTSync Corp.)

The Discrete Event System Specification (DEVS) is a general modeling formalism with sound semantics founded on a system theoretic basis. It can be used as a base for the development of specialized modeling formalisms. Usually, the extensions of DEVS expand the classes of systems models that can be represented in DEVS. However, with a growing number in new variants of DEVS and an increasing number of problems to be solved using discrete simulation techniques, it is necessary to define the relations among different approaches. This paper presents a conceptual modeling perspective applied to DEVS extensions that structure a framework over the traditional modeling and simulation approach. The framework provides a multilevel structure to analyze the features required for each extension type. Two main types of extensions are identified: variants and subclasses. In order to illustrate the proposed guidelines, the Routed DEVS formalism is presented as example of the subclass type.

Co-simulation of Hardware RTL and Software System Using FMI / Masudul Hassan Quraishi, Hessam Sarjoughian, and Soroosh Gholami (Arizona State University)

Software-hardware co-design enabled with co-simulation is useful for building embedded computing systems. Indispensable to design is developing hardware and software simulation models at appropriate abstraction levels. Toward this goal, this paper presents a study of combined Register-Transfer-Level (RTL) and software system modeling. Specifically, composition of hardware and software models is proposed and a co-simulation environment to simulate the models is developed. The hardware and software parts of a prototypical Network on Chip (NoC) system are modeled and simulated. The hardware part is specified at RTL level using the DEVS Suite Simulator and the software part defined as a MATLAB script. A Functional Mock-up Interface (FMI) is developed for the DEVS-Suite Simulator to support hardware and software model coupling and co simulation. This study details modular development of hardware and software models executing on disparate environments instead of employing a monolithic modeling method supported with a monolithic simulation engine.

A Symmetric Formalism for Discrete Event Simulation with Agents / Rhys Goldstein, Simon Breslav, and Azam Khan (Autodesk Inc.)

In designing a general modeling formalism for domain experts, a key challenge is to support a broad selection of their preferred paradigms yet minimize their exposure to complexity. With this aim, a formalism called Symmetric DEVS is proposed for specifying models that incorporate elements of discrete event simulation, dataflow programming, and agent-based modeling. Symmetric DEVS is based on the Discrete Event System Specification (DEVS) formalism, but differs in that atomic and composite nodes for discrete events are complemented with function and collection nodes for dataflow and agents. Like DEVS, nodes communicate over simulated time via message ports, but they also feature flow ports accommodating initialization and finalization operations. To minimize conceptual complexity, specifications are pared down to the essential elements and formulated to exhibit a high degree of symmetry. This paper defines the mathematical elements of Symmetric DEVS and presents an example of each of the four types of nodes.

NETWORKS AND COMMUNICATION / R24

Network Simulation: Repeatability and Performance
Bruno Tuffin (Inria)

On Repeatable Emulation in Virtual Testbeds / Vignesh Babu and David M. Nicol (University of Illinois at Urbana Champaign)

Virtual testbeds are essential tools for evaluation of cyber-security problems and cyber-security solutions in embedded control systems such as those that control the power grid. However, without explicit control, virtual testbed behavior is not repeatable, which limits our ability to replay a testbed experiment

to re-create a surprising event, or even isolate and fix a bug. In this paper we consider extensions to TimeKeeper emulation framework aimed at improving its repeatability. One approach steps through assembly language instructions, the other asks emulated applications to report their own progress through virtual time. Empirical data demonstrates the potential of our proposals.

Fluid-Flow and Packet-Level Models of Data Networks Unified Under a Modular/Hierarchical Framework: Speedups and Simplicity, Combined / Matias Bonaventura and Rodrigo Castro (Universidad de Buenos Aires, ICC-CONICET)

As network technologies undergo an exponential growth in terms of bandwidth and topology complexity, the gap is worsened between the performance of network simulation techniques and real network scenarios. Fluid-flow models for network dynamics are a well know option for reducing simulation overhead while offering useful averaged approximations of network metrics. Yet, the methods and tools established in the packet-level simulation community are alien to those used in continuous system modeling by means of differential equations. This hinders the synergy between specialists in both techniques. In this work, we present a novel modeling methodology and simulation tool to unify the experience of designing network simulation models both with fluid-level and packet-level techniques under a single modular and hierarchical formal framework. We verified the efficacy of our approach both in terms of simulation speedups and modeling simplicity for canonical network simulation scenarios.

Leveraging Shared Memory in the ROSS Time Warp Simulator for Complex Network Simulations / Caitlin J. Ross (Rensselaer Polytechnic Institute); Jianping Kelvin Li (University of California, Davis); Misbah Mubarak (Argonne National Laboratory); Christopher D. Carothers (Rensselaer Polytechnic Institute); Kwan-Liu Ma (University of California, Davis); and Robert B. Ross (Rensselaer Polytechnic Institute)

Scalability of parallel discrete-event simulation (PDES) systems is key to their use in modeling complex networks at high fidelity. In particular, intranode scalability is important due to the prevalence of many-core systems, but MPI communication between cores on the same node is known to have drawbacks (e.g., software overheads). We have extended the ROSS optimistic PDES framework to create memory pools shared by MPI processes on the same node in order to reduce on-node MPI overhead. We perform experiments to compare the performance of shared memory ROSS with pure MPI ROSS on two different systems. For the experiments, we use several models that exhibit a variety of characteristics to understand the conditions where shared memory can benefit the simulation. In general, higher remote event rates means that simulations are more likely to benefit from using shared memory, but this may also be due in part to improved rollback behavior.

SIMULATION EDUCATION / R15

Panel: Education on Model Simplification
Kathy Kotiadis (Canterbury Christ Church University)

Panel: Education on Simulation Model Simplification – Beyond Rules of Thumb / Durk-Jouke Van der Zee (University of Groningen), Antuela Tako (Loughborough University), Paul Fishwick (The University of Texas at Dallas), Stewart Robinson (Loughborough University), and Oliver Rose (Universität der Bundeswehr München)

Most management problems addressed by simulation studies can be characterized as complex and difficult to analyze. Simplification is instrumental in creating and employing simulation models that are useful – by focusing on those system elements that matter, and feasible – by reducing study efforts. Although simplification is considered a fundamental modelling activity, simulation educational support for mastering associated modelling skills is limited. Main textbooks either do not address this topic or tend to restrict their guidance to a few rules of thumb. This reflects how the topic of simulation model simplification is underdeveloped, despite the field of simulation being around 50 years of age. The purpose of this panel is to initiate a discussion about the way we teach simulation model simplification with the view to identifying improvements. This paper addresses the motivation for the panel, and presents panelists' "positions" about the way forward for education on simulation model simplification.

SIMULATION FOR A NOBLE CAUSE / R22

Simulation in contemporary achievements
David Poza (University of Valladolid)

Transition to Alternative Fuel Vehicles: A Distributive Justice Perspective / Wissam EL Hachem and Pietro De Giovanni (ESSEC Business School)

In this paper, we build a system dynamics model to investigate the ongoing endeavor to transition from conventional non-renewable transportation systems to renewable ones. The model focuses on light to mid duty vehicles in the private transportation sector. The literature focuses on the environmental and economic aspects of such a transition. We adopt distributive justice as a new angle, define it as access to transportation, justify its relevance by considering it a vital need for people to actualize their capabilities in society and propose a measure to quantitatively measure it in our context. There are several layers of tradeoffs in policy appraisal, yet we are able to catalyze the transition to AFV's while improving its sustainability. A policy that ensures such a harmonious behavior is one that focuses on the GHG emissions with little to no emphasis on the AFV quotas, while providing support for consumers to switch to AFV's.

Generic Bus Route Simulation Model and Its Application to a New Bus Network Development for Caieiras City, Brazil / Wilson Inacio Pereira (Simulate Simulation Technology) and Leonardo Chwif (Mauá Institute of Technology)

The issue of adequate urban bus routes is very important to general population life quality. It is shown that in Brazil, 25% of the citizens from urban areas uses buses as the main transportation method. In general, bus routes are created and modified without proper methodology or analysis. Discrete Event Simulation is a paradigm that can take into consideration the variability and dynamic nature of bus routes and, therefore, provide valuable insights especially when one is trying to propose a change in an existing bus network. On the other hand, a simulation model for general bus routes is not easy to develop. The present work proposes a generic simulation model for radial networks in order to take into account data which is normally available at buses networks and, then, apply this model to the case of Caieiras city bus network redesign.

Designing Modeling and Simulation User Experiences: An Empirical Study Using Virtual Art Creation / Krzysztof J. Rechowicz, Saikou Y. Diallo, and D'An Knowles Ball (Old Dominion University) and Joshua Solomon (Solomon Solutions)

For decades, users have been interacting with software through graphical user interfaces. This is also true for modeling and simulation (M&S) tools, a paradigm that affects how models are built and simulated. It also impacts how results are presented, 1) preventing non-experts from using M&S tools, and 2) excluding people who are atypical on a sensory spectrum. This paper focuses on the exploration of key factors contributing to designing M&S user experiences as an approach to mitigate existing thresholds and establish M&S as a means to improving people's lives. We perform an empirical study with artists, who express creative skill and imagination in a visual form, creating in virtual environments. We report on results of a user experience survey completed after a creative session in virtual environments. Finally, we discuss how these results can benefit M&S tool development.

SIMULATION OPTIMIZATION / J2

SO in Smart Production
Klaus Altendorfer (Upper Austrian University of Applied Science)

Using Aggregated Discrete Event Simulation Models And Multi-Objective Optimization To Improve Real-World Factories / Simon Lidberg, Leif Pehrsson, and Amos H.C. Ng (University of Skövde)

Improving production line performance and identifying bottlenecks using simulation-based optimization has been shown to be an effective approach. Nevertheless, for larger production systems which are consisted of multiple production lines, using simulation-based optimization can be too computationally expensive, due to the complexity of the models. Previous research has shown promising techniques for aggregating production line data into computationally efficient modules, which enables the simulation of higher-level systems, i.e., factories. This paper shows how a real-world factory flow can be optimized by applying the previously mentioned aggregation techniques in combination with

multi-objective optimization using an experimental approach. The particular case studied in this paper reveals potential reductions of storage levels by over 30%, lead time reductions by 67%, and batch sizes reduced by more than 50% while maintaining the delivery precision of the industrial system.

Machine Learning Based Construction Simulation and Optimization / Kailun Feng and Shiwei Chen (Harbin Institute of Technology, Luleå University of Technology) and Weizhuo Lu (Luleå University of Technology)

Building construction comprises interaction and interdependence among processes. Discrete-event simulation (DES) is widely applied to model these processes interaction. To find optimal construction plans, optimization technique is usually integrated with DES. However, present simulation-optimization integrated method directly invokes simulation model within optimization algorithms, which is found significantly computationally expensive. This study proposes a machine learning based construction simulation and optimization integrated method. After trained by DES, the machine learning model accelerates simulation-optimization integration by nearly real-time providing fitness evaluation within optimization. This method was implemented into a real construction project for construction time-cost-environment optimization. Results show that proposed machine learning based method significantly reduce computing time compared with original simulation-optimization integration. Less than 1% of construction cost and time improvement were miss, while greenhouse gas emissions obtained same performance. The new method could be a more effective DES and optimization integration approach for practical engineering application.

Regression Methods for Surrogate Modeling of a Real Production System Approximating the Influence on Inventory and Tardiness / Johannes Karder, Klaus Altendorfer, Andreas Beham, and Andreas Peirleitner (University of Applied Sciences Upper Austria)

Simulation optimization is often conducted by applying optimization heuristics (e.g., genetic algorithms) whereby the simulation model delivers the objective function value for the respective parameter set. For real world simulation models, their evaluation time is a crucial constraint. This holds especially for material requirements planning (MRP) parameter optimization of real production systems with many products, because of an extensive search space. Approximating the objective function values by surrogate models can be applied to reduce the search space. Based on a real world production system simulation model, the performance of different regression models to identify simple surrogate models for fast objective function approximation is evaluated in this paper. Specifically, a focus is put on the relationship between the MRP parameters: lot-size and planned lead time, and the performance indicators: inventory and tardiness costs. The paper evaluates a set of simple regression models and compares their objective function fit.

VENDOR TUTORIALS / R25

Simio / Systems Navigator

The Applications of Simio Simulation and Scheduling in Industry 4.0 / Renee Thiesing (Simio LLC)

Simulation has traditionally been applied in system design projects where the basic objective is to evaluate alternatives and predict and improve the long-term system performance. In this role, simulation has become a standard business tool with many documented success stories. Beyond these traditional system design applications, simulation can also play a powerful role in scheduling by predicting and improving the short-term performance of a system. In the manufacturing context, the major new trend is towards digitally connected factories that introduce a number of unique requirements which traditional simulation tools do not address. Simio has been designed from the ground up with a focus on both traditional applications as well as advanced scheduling, with the basic idea that a single Simio model can serve both purposes. In this paper we will focus on the application of Simio simulation and scheduling in the Industry 4.0 environment.

Optimizing Manufacturing and Supply Chains Using Digital Twin Systems / Rienk Bijlsma and Daan Merkestein (Systems Navigator)

Systems Navigator is proud to present two compelling case studies of digital twin systems, where with the help of our advanced discrete event simulation technology, our clients have been able to save money, increase customer satis-

faction and reduce risk. The first case study is about a simulation model for a new coil warehouse in the steel industry that is used for analysis & optimization of the layout. The final solution consists of a Simio simulation model, with a Scenario Navigator user interface. The second case study is about a simulation model for a live supply chain of marine shipments in the oil industry, that is used to design the supply chain, as well as predict possible future scenario's. This operational system runs on an Arena simulation model, and is operated through a Scenario Navigator user interface.

Tuesday 10:00a.m.-11:30a.m.

ADVANCED TUTORIALS / R23

Parametric Verification by Machine Learning
Collin Erickson (Northwestern University)

Bayesian Statistical Parametric Verification and Synthesis by Machine Learning / Luca Bortolussi (University of Trieste), Guido Sanguinetti (University of Edinburgh), and Simone Silvetti (Esteco SpA)

We consider the problem of parametric verification, presenting a recent statistical method to perform parametric verification of linear time properties of stochastic models, estimating the satisfaction probability as a function of model or property parameters. The approach leverages Bayesian Machine Learning based on Gaussian Processes. Under mild conditions on continuity of parameters of the satisfaction probability, it can be shown that property satisfaction is a smooth function of such parameters. Gaussian Processes can effectively capture this smoothness and obtain more-accurate estimates of satisfaction probabilities by transferring information across the parameter space. We leveraged this approach to efficiently solve several tasks, like parameter synthesis, system design, counterexample generation, and requirement synthesis. In this tutorial, we will introduce the basic ideas of the approach and give an overview of the different applications.

AGENT-BASED SIMULATION / R5

Methodology
Luis Gustavo Nardin (Brandenburg University of Technology)

Agent-based Simheuristics: Extending Simulation-Optimization Algorithms via Distributed and Parallel Computing / Javier Panadero and Angel Juan (Universitat Oberta de Catalunya), Canan G. Corlu (Boston University), Jose Miguel Mozos (Universitat Oberta de Catalunya), and Bhakti Stephan Onggo (Trinity College Dublin)

This paper presents a novel agent-based simheuristic (ABSH) approach that combines simheuristic and multi-agent system to efficiently solve stochastic combinatorial optimization problems. In an ABSH approach, multiple agents cooperate in searching a near-optimal solution to a stochastic combinatorial optimization problem inside a vast space of feasible solutions. Each of these agents is a simheuristic algorithm integrating simulation within a metaheuristic optimization framework. Each agent follows a different pattern while exploring the solution space. However, all simheuristic agents cooperate in the search of a near-optimal solution by sharing critical information among them. The distributed nature of the multi-agent system makes it easy for ABSH to make use of parallel and distributed computing technology. This paper discusses the potential of this novel simulation-optimization approach and illustrates, with a computational experiment, the advantages that ABSH approaches offer over traditional simheuristic ones.

Translation of String-and-Pin-based Shortest Path Construction into Data-Scalable Agent-based Computational Models / Yun-Ming Shih, Collin Gordon, and Munehiro Fukuda (University of Washington Bothell) and Jasper van de Ven and Christian Freksa (University of Bremen)

From the viewpoint of strong spatial cognition in graph problems, the shortest path search can be solved in one physical action using strings and pins that respectively represent graph edges and vertices. By pulling a start and an end pin, we can identify a series of stretched strings as the shortest path. We use agent-based models (ABMs) to translate this action into computational representations. Assuming that a set of strings and pins are hung on a wall with a start pin, agents are disseminated downward to a destination as gravity forces.

We implemented three models: a discrete-event, an asynchronous, and an aggregated agent dissemination on top of the MASS (multi-agent spatial simulation) library. To address large-scale network environments, we blended HDFS into MASS so that a graph data set is read over a cluster system in parallel. This paper presents these ABM implementations and performance measurements over a cluster system.

Adding Agent Concepts to Object Event Modeling and Simulation / Gerd Wagner and Luis Gustavo Nardin (Brandenburg University of Technology)

Object Event Modeling and Simulation (OEM&S) is a general Discrete Event Simulation paradigm combining object-oriented modeling with the event scheduling paradigm. We show how to extend OEM&S by adding concepts of agent-based modeling and simulation, resulting in a framework that we call Agent/Object Event Modeling and Simulation (A/OEM&S). The main point for such an extension is to define agents as special objects, which are subject to general (physical) laws of causality captured in the form of event rules, and which have their own behavior allowing them to interact with their inanimate environment and with each other. Because agent behavior is decoupled from physical causality, an A/OE simulator consists of an environment simulator, which simulates the physical world (the objective states of material objects), and agent simulators, which simulate the internal (subjective) states of agents and their behaviors.

ANALYSIS METHODOLOGY / CONGRESS HALL

Estimation and Sampling
Pierre L'Ecuyer (University of Montreal; GERAD, CIRRELT)

On a Generalized Splitting Method for Sampling From a Conditional Distribution / Pierre L'Ecuyer (University of Montreal; GERAD, CIRRELT); Zdravko I. Botev (University of New South Wales); and Dirk P. Kroese (The University of Queensland)

We study the behavior of a splitting method for sampling from a given distribution conditional on the occurrence of a rare event. The method returns a random-sized sample of points such that unconditionally on the sample size, each point is distributed exactly according to the original distribution conditional on the rare event. For a cost function which is nonzero only when the rare event occurs, the method provides an unbiased estimator of the expected cost, but if we select at random one of the returned points, its distribution differs in general from the exact conditional distribution given the rare event. However, we prove that if we repeat the algorithm n times and select one of the returned points at random, the distribution of the selected point converges to the exact one in total variation when n increases.

Exact Posterior Simulation From The Linear LASSO Regression / Zdravko Botev and Yi-Lung Chen (UNSW Sydney), Pierre L'Ecuyer (University of Montreal), Shev MacNamara (University of Technology Sydney), and Dirk P. Kroese (University of Queensland)

The current popular method for approximate simulation from the posterior distribution of the linear Bayesian LASSO is a Gibbs sampler. It is well-known that the output analysis of an MCMC sampler is difficult due to the complex dependence amongst the states of the underlying Markov chain. Practitioners can usually only assess the convergence of MCMC samplers using heuristics. In this paper we construct a method that yields an independent and identically distributed (iid) draws from the LASSO posterior. The advantage of such exact sampling over the MCMC sampling is that there are no difficulties with the output analysis of the exact sampler, because all the simulated states are independent. The proposed sampler works well when the dimension of the parameter space is not too large, and when it is too large to permit exact sampling, the proposed method can still be used to construct an approximate MCMC sampler.

Hyperparameter Optimization for Approximate Bayesian Computation / Prashant Singh and Andreas Hellander (Uppsala University)

Approximate Bayesian computation is a popular methodology for simulation-based parameter inference in scenarios where the likelihood function is either analytically intractable or computationally infeasible. The likelihood of simulator parameters fitting given data is approximated by iteratively simulating samples that are generated according to a specified prior distribution. The convergence speed and the quality of inference are highly sensitive to the choice of hyper-

parameters such as the chosen summary statistic, the value of the acceptance threshold and the distance function. The choice is typically left to the domain expert as summary statistics vary across disciplines and threshold values are problem-specific. This work explores automated hyperparameter optimization for approximate Bayesian computation using Bayesian optimization as an alternative to time consuming manual selection. The problem setting assumes availability of a fast low-fidelity simulator, which is used during the optimization process. The optimized hyperparameters are then used to perform inference using the high-fidelity simulator.

COMPLEX, INTELLIGENT, ADAPTIVE AND AUTONOMOUS SYSTEMS / R22

Simulation Analysis

Xiaobing Li (UTK; University of Tennessee, Knoxville)

A Simulation Testbed for the Analysis of Desired Emergent Properties in System Running in Dynamic and Contested Environments / Claudia Szabo (University of Adelaide); Dustin Craggs (The University of Adelaide); and Wayne Johnson, Gregory Judd, and Keith French (Defence Science and Technology Group)

Designing complex systems with a specific emergent property is challenging even in perfect environmental conditions, and several additional challenges are introduced in contested, dynamic environments such as ongoing battles or military exercises. An example of a desired emergent property is disseminating information in a timely manner without causing significant network disruptions. While military communication strategies exist, their evaluation is performed in costly real-life deployments with limited exploratory capability. In this paper, we propose to achieve timely information dissemination through a rule-based expert system that adapts to network and operational context changes by change the priority of messages sent to the network. To analyse this emergent behavior, we present an evaluation simulation testbed that explores various operational conditions for the evaluation of communication strategies in a land-exercise focused scenario.

Evaluating and Optimizing Component-based Robot Architectures using Network Simulation / Daniel Krauß (Karlsruhe Institute of Technology); Philipp Andelfinger (TUMCREATE Ltd and Nanyang Technological University); and Fabian Paus, Nikolaus Vahrenkamp, and Tamim Asfour (Karlsruhe Institute of Technology)

Modern service and humanoid robots are comprised of multiple computers distributed among the robots' hardware. During task execution, several software components are executed in parallel on the connected machines. Due to the complex control loops and communication requirements of robot tasks, a suitable assignment of software components to the available hardware units is necessary to achieve low reaction times. Currently, there is a lack of works on approaches to evaluate intra-robot communication. We propose a coupling between the robotics framework ArmarX and the network simulator OMNeT++ to support the evaluation and optimization of robot architectures. Our approach allows unmodified robot components to communicate across simulated network interconnects. In a case study, we examine the influence of different hardware assignments of software components on task execution times. We show that the timing information present in the simulation-based evaluations enables more efficient hardware assignments when compared to static graph partitioning.

Simulation Analysis of a Deep Reinforcement Learning Approach for Task Selection by Autonomous Material Handling Vehicles / Maojia Patrick Li, Prashant Sankaran, Michael E. Kuhl, Amlan Ganguly, Andres Kwasinski, and Raymond Ptucha (Rochester Institute of Technology)

The use of autonomous vehicles is a growing trend in the material handling and warehousing. Some challenges that face material handling include the navigation within a warehouse, precision localization and movement, and task selection decisions. In this paper, we address the issue of task selection. In particular, we develop a deep reinforcement learning methodology to enable a vehicle to select from among multiple tasks and move to the closest task in the context of material handling in a warehouse. To evaluate the deep reinforcement learning methodology, we conduct a simulation-based experiment to generate scenarios to first train and then test the capabilities of the method. The results of the experiment show that the method performs well under the given conditions.

CYBER-PHYSICAL SYSTEMS / R11

Analysis and Methodologies for CPS
Antonio Augusto Frohlich (UFSC)

Forecasting Cyber Maintenance Costs with Improved Scan Analytics Using Simulation / Theodore T. Allen and Enhao Liu (The Ohio State University)

This article proposes a discrete event simulation model of an organization that maintains computer hosts and incurs several millions of dollars in maintenance and incident response costs. The common maintenance policy is referred to as "out-of-sight is out-of-mind" (OSOM) because the majority of hosts are absent from scans and ignored. Hosts are "dark" (absent) because they are not accessible (turned off or with restricted permissions). The proposed model is used to compare OSOM with alternatives including improved analytics that make dark host vulnerabilities visible. Findings clarify the apparent benefits of OSOM unless indirect costs for intrusions or improved policies are applied. Also, benefits from using Windows operating systems and improved policies are clarified including millions in expected savings (vs. Linux).

Digital Manufacturing: Requirements and Challenges for Implementing Digital Surrogates / Guodong Shao (NIST) and Deogratias Kibira (University of District of Columbia)

A key challenge for manufacturers today is efficiently producing and delivering products on time. Issues include demand for customized products, changes in orders, and equipment status change, complicating the decision-making process. A real-time digital representation of the manufacturing operation would help address these challenges. Recent technology advancements of smart sensors, IoT, and cloud computing make it possible to realize a "digital twin" of a manufacturing system or process. Digital twins or surrogates are data-driven virtual representations that replicate, connect, and synchronize the operation of a manufacturing system or process. They utilize dynamically collected data to track system behaviors, analyze performance, and help make decisions without interrupting production. In this paper, we define digital surrogate, explore their relationships to simulation, digital thread, artificial intelligence, and IoT. We identify the technology and standard requirements and challenges for implementing digital surrogates. A production planning case is used to exemplify the digital surrogate concept.

Composition of Numerical Integrators in the HyFlow Formalism / Fernando Barros (University of Coimbra)

The representation of complex Cyber-Physical Systems usually requires the ability to combine models described in different modeling formalisms and involving several numerical methods. While ordinary differential equations (ODEs) are a common formalism for representing continuous systems, their solution cannot be efficiently and accurately accomplished by a single numerical integrator. A plethora of methods have been developed to tackle several issues including efficiency, accuracy, and stiffness. Given the variety of methods, a common representation to enable their interoperability is still a major research challenge. In this paper, we introduce the Hybrid Flow System Specification formalism (HyFlow) as a general framework for describing numerical integrators in a modular form. Each numerical method is represented as a particular model in the formalism. Co-simulation is then enabled, since all HyFlow models can be composed by design. In this paper, we show examples demonstrating the co-simulation of geometric, pulse, and exponential numerical integrators.

HEALTHCARE APPLICATIONS / R12

Modeling Real-World Clinics
Jacqueline Griffin (Northeastern University)

Simulation Tool to Evaluate Electronic Consultations in Rheumatology / Breanna P. Swan and Chloe L. Shevlin (North Carolina State University) and Alex Cho and Donna Phinney (Duke University Health System)

Complex patients, limited specialists, and high demand create long referral queues ill-equipped to deliver timely quality care. One approach to reduce queue length is for specialists to review referrals through an electronic consultation (e-consult) and determine if 1) the patient requires a specialty appointment or 2) the primary care physician can continue care with the specialist's recommendations. As inappropriate patients are removed from the queue, it is hypothesized

that lead times will decrease and the system be more efficient at delivering the right care to the right patient at the right time. A discrete-event simulation was built to estimate the impact e-consults have on Rheumatology clinics at Duke Health; specifically considering lead time, queue length, and specialists' workload. This is an adaptable tool with visualizations for which any specialty clinic, each with its own complex challenges, could estimate the impact e-consults have on delivering quality care to referred patients.

Modeling an Information-based Community Health Intervention on the South Side of Chicago / Chaitanya Kaligotla, Jonathan Ozik, Nicholson T. Collier, and Charles M. Macal (Argonne National Laboratory) and Emily Abramsohn, Stacy T. Lindau, and Elbert Huang (The University of Chicago)

We describe the development and application of a model that simulates the impact of CommunityRx, an information-based health intervention, on the utilization of community-based resources. The model includes a synthetic population of agents matching the sociodemographic characteristics of the South Side of Chicago, along with their activities and behaviors. We simulate the information-based intervention and model agent decision-making about using community resources to maintain health, based on a dynamic dosing of information about community resources, gained through interactions and experience. Through in silico experiments, our model aims to demonstrate the flow and spread of information from primary agents to others in the community, and through these dynamic interactions, the impact of an individual-level information intervention on resource utilization.

Building a Flexible Simulation Model for Modeling Multiple Outpatient Orthopedic Clinics / Nurul Suhaimi, Vahab Vahdat, and Jacqueline Griffin (Northeastern University)

Often large health care organizations will have multiple satellite clinics in addition to the primary flagship location. The value of having multiple clinics includes the ability to better serve patients by improving accessibility while also increasing efficiencies from common structures and policies. Unlike most simulation models of health care clinics, which are uniquely designed for one specific location and are not easily adapted without significant effort, we develop one flexible discrete-event simulation model to represent two orthopedic centers. In addition to demonstrating the validity of employing the same model for two clinics, a graphical user interface is constructed to enable the clinic managers to modify simulation parameters, minimizing the need for future model adaptations. The value of the simulation model is verified by evaluating the effects of new policies impacting the role of mid-level providers and results show that the best policy for improving timeliness of care varies among clinics.

HYBRID SIMULATION / R6

Hybrid Modeling Paradigms
Anatoli Djanatliev (University of Erlangen-Nuremberg)

From Hybrid Simulation to Hybrid Systems Modelling / Navonil Mustafee and John Powell (University of Exeter)

Hybrid Simulation (HS) is the combined application of simulation approaches like SD, DES and ABS in the model implementation stage of a simulation study. Its objective is to better represent the system under scrutiny. Hybrid Systems Modelling (HSM), on the other hand, is the combined application of simulation with methods and techniques from disciplines such as Applied Computing, Computer Science, Engineering and the wider OR. HSM can be applied to multiple stages of a simulation study. In this paper, we present a classification of HS and extend it to include HSM approaches which use simulation with other OR techniques. The paper contributes to the debate on what constitutes HS and offers a unifying conceptual representation for mixing simulation approaches with HSM methods and techniques.

Combining Data Farming and Data Envelopment Analysis for Measuring Productive Efficiency in Manufacturing Simulations / Niclas Feldkamp, Soeren Bergmann, Erik Borsch, Magnus Richter, Steffen Strassburger, and Rainer Souren (Ilmenau University of Technology)

Discrete event simulation is an established methodology for investigating the dynamic behavior of complex manufacturing and logistics systems. In addition to traditional simulation studies, the concept of data farming and knowledge discovery in simulation data is a current research topic that consist of broad

scale experimentation and data mining assisted analysis of massive simulation output data. While most of the current research aims to investigate key drivers of production performance, in this paper we propose a methodology for investigating productive efficiency. We therefore developed a concept of combining our existing approach of data farming and visual analytics with data envelopment analysis (DEA), which is used to investigate efficiency in operations research and economics. With this combination of concepts, we are able to determine key factors and interactions that drive productive efficiency in the modeled manufacturing system, but also to identify the most productive settings.

Designing Care Pathways Using Simulation Modeling and Machine Learning / Mahmoud Elbattah (Université de Picardie Jules Verne); Owen Molloy (National University of Ireland, Galway); and Bernard Zeigler (RTSync)

The development of care pathways is increasingly becoming an instrumental artefact towards improving the quality of care and cutting costs. This paper presents a framework that incorporates Simulation Modeling along with Machine Learning (ML) for the purpose of designing pathways and evaluating the return on investment of implementation. The study goes through a use case in relation to elderly healthcare in Ireland, with a particular focus on the hip-fracture care scheme. Initially, unsupervised ML is utilized to extract knowledge from the Irish Hip Fracture Database. Data clustering is specifically applied to learn potential insights pertaining to patient characteristics, care-related factors, and outcomes. Subsequently, the data-driven knowledge is utilized within the process of simulation model development. Generally, the framework is conceived to provide a systematic approach for developing healthcare policies that help optimize the quality and cost of care.

INTRODUCTORY TUTORIALS / R31

Tutorial on Monte Carlo Tree Search
Marcelus Lima (Universitat Pompeu Fabra)

Monte Carlo Tree Search: A Tutorial / Michael Fu (University of Maryland, Smith School of Business)

Monte Carlo tree search (MCTS) is a general approach to solving game problems, playing a central role in Google DeepMind's AlphaZero and its predecessor AlphaGo, which famously defeated the (human) world Go champion Lee Sedol in 2016 and world #1 Go player Ke Jie in 2017. Starting from scratch without using any domain-specific knowledge (other than the game rules), AlphaZero defeated not only its ancestors in Go but also the best computer programs in chess (Stockfish) and shogi (Elmo). In this tutorial, we provide an introduction to MCTS, including a review of its history and relationship to a more general simulation-based algorithm for Markov decision processes (MDPs) published in a 2005 Operations Research article; a demonstration of the basic mechanics of the algorithms via decision trees and the game of tic-tac-toe; and its use in AlphaGo and AlphaZero.

LOGISTICS, SCM, TRANSPORTATION / R21

Intralogistics
Hans-Peter Barbey (Fachhochschule Bielefeld)

Reducing Picker Blocking in a High-level Narrow-Aisle Order Picking System / Teun van Gils, An Caris, and Katrien Ramaekers (Hasselt University)

New market developments force warehouses to handle a large number of orders within short time windows. Although research optimizing storage assignment and picker routing is extensive, there remains a gap between academic research and practice. Real-life issues, such as picker blocking, high-level storage locations, precedence constraints, and safety constraints, have been considered insufficiently while optimizing order picking planning problems. This paper goes beyond the current academic state-of-the-art by showing the effects of these real-life issues on order picking efficiency and explaining the importance of incorporating these real-life issues while planning order picking operations. Multiple horizontal and vertical storage assignment policies, as well as multiple routing policies are simulated with the aim of reducing travel and waiting times. The results of a full factorial ANOVA are used to formulate managerial guidelines to increase order picking efficiency in narrow-aisle systems to address the new market developments resulting in enhanced customer service.

Simulation Analysis of Large-scale Shuttle Vehicle-type Mini-load AS/RS Systems / Rie Gaku (St. Andrew's University) and Soemon Takakuwa (Chuo University)

Shuttle Vehicle-type Mini-load automated storage and retrieval systems (SVM-AS/RSs) allow for rapid storage and retrieval, enhancing the buffering function of flexible storage and sorting operations. The systems considered in this study consist of lightweight shuttle vehicles installed at each storage level, storing and retrieving lifters, layer conveyors connecting lifters and shuttle vehicles, and incoming and outgoing aisle conveyors. First, a method is demonstrated whereby it can be determined whether lifters or shuttle vehicles are the bottlenecks in a designated system. It is then shown how simulation can be used to precisely analyze the performance of different layouts, taking storage-location allocation rules and operation priorities into consideration. This work shows that key performance indicators derived from the results of such a simulation analysis are valuable tools for the selection of the most effective and economical set of specifications for an SVM-AS/RS under given conditions of operation priorities.

Simulation-based Planning and Dimensioning of an Automatic Laundry Storage and Retrieval Unit with Dynamic Storage Location Sizes / Marcel Müller, Tobias Reggelin, Stephan Schmidt, and David Weigert (Otto von Guericke University Magdeburg)

Industrial laundries in Germany face a high pressure to increase their efficiency due to an ongoing market concentration. While many processes in an industrial laundry are already highly automated and optimized, order picking is still done manually. As RFID proliferates in industrial laundries, goods become traceable and identifiable. This enables the effective use of automated picking systems. Automation systems in the laundry industry face the challenge of pliable (form unstable) goods. This paper shows how the planning and dimensioning of an automated Laundry Order Consolidation System (LOCSys) can be supported by simulation modelling, already beginning in the early conception stage of the system.

MANUFACTURING APPLICATIONS / R2

Business Decision Support

Klaus Altendorfer (Upper Austrian University of Applied Science)

Using Monte-Carlo Simulation to Measure the Business-relevant Impact of Planning Uncertainty on Field Service Delivery / Clemens Wolff, Michael Vössing, and Niklas Kühl (Karlsruhe Institute of Technology)

Today, delivery of industrial maintenance services is planned under uncertainty, as, for example, the true task duration is unknown. Thus, providers rely on estimates at the stage of planning. During operations, the true task duration becomes known which results in a schedule update. This work evaluates the effects of information uncertainty on business-relevant performance indicators in industrial maintenance. We present a simulation model to reflect the evolution of information and the schedule revision during operations. Within a simulation experiment, we measure the business-relevant impact of different uncertainty levels on operations. Indeed, the findings of our research confirm the common understanding that reduced uncertainty at the stage of planning has a positive effect on service delivery. However, our research also shows that in order to achieve business-relevant impact in service delivery quality, the reduction of uncertainty at the stage of planning needs to reach a certain threshold.

Simulating an Integrated Revenue Management Approach in a Production System with Product Substitution / Maha Ben Ali, Sophie D'Amours, and Jonathan Gaudreault (Université laval, FORAC research consortium) and Marc-André Carle (Université TÉLUQ, FORAC research consortium)

Most revenue management publications dealing with substitutable products in a manufacturing context have focused on pricing issues. They consider that substitution is a customer's decision which occurs as a response to product price differences. In our study, substitution is considered as the firm's policy. We focus on the extension of the revenue management to practical applications in manufacturing and we are motivated by the Canadian softwood lumber case where product substitution is a common demand fulfillment practice. We aim, first, to propose a generic consumption model integrating both capacity control and product substitution decisions and second, to evaluate, using a rolling horizon simulation, the performance of this integrated model in different settings compared to common demand fulfillment approaches. In addition to practical implications, our study contributes to the existing demand fulfillment literature

since we simulate different consumption models integrated with a Sales and Operations Planning model.

A Stepwise Implementation of the Virtual Factory in Manufacturing Industry / Amanda Dalstam, Marcus Engberg, Daniel Nåfors, and Björn Johansson (Chalmers University of Technology) and Anneli Sundblom (SKF Sverige AB)

A big challenge for manufacturers today is to create a flexible and efficient production system. One way of managing this challenge is to establish a virtual factory, a virtual model of the production unit. Working smarter by using the advantages that digitalization implies enables production of personalized products at increasing speed. This paper explores how to implement such a concept by stepwise increasing the maturity of the virtual factory. Evaluated at a large-scale Swedish manufacturer, local needs and enabling technologies benchmarked at industry leaders have been identified and strategically mapped to their corresponding maturity step. This paper shows that the implementation of a virtual factory relies on standardized work procedures, ensuring its use as a decision aid throughout the company. Implementing a virtual factory in this manner will facilitate user-driven development and more accurate decision making, generating support for efficient production systems.

MASM / R14

Scheduling and Qualification Management
Lars Moench (University of Hagen)

Optimization versus Construction of Transport Schedules to Reduce Travel Time Variability and Avoid Congestions in Conveyor-based AMHS for Wafer Fabs / Clemens Schwenke, Sebastian Jannasch, and Klaus Kabitzsch (TU Dresden)

Advanced transport scheduling for conveyor-based automated material handling systems (AMHS) in semiconductor fabricating facilities (wafer fabs) can reduce transport times and thus cycle times. Commonly, transport operations of arriving wafer lots at conveyor junctions, such as rotary tables, are sequenced ad-hoc by myopic first-come-first-serve policies. In contrast, improved transport schedules for the transport operations can be produced ahead of the time in conjunction with the overall production schedule for process operations. More precisely, such a transport schedule can either be sequentially constructed by fixing one transport after another, or it can be optimized by simultaneously fixing several conflicting transports. Hence, two conceptually different transport scheduling methods, which both avoid congestions by enforcing a no-wait constraint, are compared with special regard to transport-related variability. Furthermore, three different AMHS models that exhibit the typical interbay-intrabay layout are used for computational experiments.

A Hierarchical Approach to Qualification Management in Wafer Fabs / Denny Kopp and Lars Mönch (University of Hagen)

We discuss a qualification management problem arising in wafer fabs. The steppers need to be qualified to process lots of different families. A qualification time window is associated with each stepper and family. The time window can be reinitialized as needed and can be extended by on-time processing of lots from qualified families. In this paper, we propose a hierarchical approach for this problem. The base-level is a dispatching strategy that takes into account qualification decisions. The medial-level consists of a mixed integer linear programming formulation for making qualification decisions, whereas the top-level is a linear programming (LP) formulation that computes target quantities for the steppers for a planning window taking fab-wide objectives into account. We present results of simulation experiments where the hierarchical approach is applied in a rolling horizon manner. The results demonstrate that the LP-based approach outperforms a heuristic to determine target quantities.

A Comparison of an CP and MIP Approach for Scheduling Jobs In Production Areas with Time Constraints and Uncertainties / Christian Maleck, Gottfried Nieke, and Karlheiz Bock (Technische Universität Dresden) and Detlef Pabst and Marcel Stehli (GLOBALFOUNDRIES Inc.)

This research is motivated by the expensive costs of scraps because of timelink misses in a semiconductor manufacturing line with tool downs. A timelink is a time constraint between defined process steps. This paper presents a mixed integer programming model (MIP) and an constraint program (CP) with downscaled time constraints. With the assistance of the survival analysis, a

safety value will be computed and included as a constant in the MIP and as a dynamic expression in the CP, to downscale the allowed time between two specific operations. The MIP and CP models are tested on a realistic production area example with different problem sizes. The quality of the solution and the performance of these two approaches are compared with each other. The test results show that the CP Model outperforms the MIP and finds much earlier usable schedules for large problem sizes.

MODELING METHODOLOGY / R26

Modeling Formalisms - II
Hans Vangheluwe (McGill University and University of Antwerp)

From Analogue to Digital: Creating Simulations through Conceptualization Boards / Jose Padilla, Saikou Diallo, and Hector Garcia (Old Dominion University)

We explore how to use conceptualization boards to familiarize students, teachers, parents, and the community in general with discrete-event simulations. We raise the question: how can we make simulations accessible to non-simulationists? We argue that with the use of tactile tools users can not only conceptualize but also create simulations. We developed a prototype board that captures discrete-event simulation's blocks like arrivals, queues, processes and resources. The board applies the concept of gamification to engage users. The board is simple to replicate and can be created with accessible material or 3D printing capabilities. Further, we propose the board be used simultaneously with software applications to facilitate the transition from analogue to digital tools. Future work investigates 1) extended simulation, 2) universal access to simulation and 3) insight generation.

Runtime Code Generation for Interpreted Domain-Specific Modeling Languages / Tom Meyer, Tobias Helms, Tom Warnke, and Adelinde Uhrmacher (University of Rostock)

Domain-specific modeling languages (DSMLs) facilitate concise and succinct model descriptions. DSMLs are commonly realized by defining a custom grammar and executing models in an interpreter. This provides flexibility in language design as well as in the implementation of simulation algorithms. However, this type of implementation can lead to a negative impact on simulation performance in comparison to implementing models in general-purpose programming languages (GPL). To mitigate this problem, we propose using runtime code generation. This allows us to replace specific parts of a model at runtime by compiling generated GPL source code. In this paper, we demonstrate the potential benefit of this concept based on ML-Rules, a DSML for modeling and simulating biochemical reaction networks. Using code generation for arithmetic expressions in ML-Rules' reaction rate functions, we were able to decrease the runtime by up to 40% in complex application scenarios.

Translating Engineering Workflow Models to DEVS for Performance Evaluation / István Dávid (University of Antwerp/Flanders Make), Yentl Van Tendeloo (University of Antwerp), and Hans Vangheluwe (University of Antwerp/Flanders Make)

Engineering workflow models are frequently used to optimize an engineering endeavor for some well-defined performance metrics, such as time-to-market or monetary costs. Static workflow analysis is often insufficient due to the complex interleavings of different activities and the interplay with limited resources. Simulation-based techniques provide a feasible alternative to static analysis. In this paper, we provide an automated translation from engineering workflow models to DEVS (Discrete Event System Specification) models, useful for simulation and subsequent performance evaluation. Our translation supports the vast majority of the essential workflow control patterns, previously identified by van der Aalst et al. Thanks to the use of simulation, our approach is able to deal with stochastically varying activity execution times and workflow decisions, potentially evolving between subsequent iterations of the workflow. Our approach is implemented in the Modelverse, where the mapping to and simulation of DEVS models remains completely hidden from the process modeler.

NETWORKS AND COMMUNICATION / R24

Network Simulation
David Nicol (University of Illinois at Urbana-Champaign)

The Impact of Queue Length Rounding and Delayed App Information on Disney World Queues / Jamol Pender, Samantha Nirenberg, and Andrew Daw (Cornell University)

Many service systems provide queue length information to customers to aid their decisions of what queue to join. One example is at Walt Disney World (WDW), where waiting times are posted to customers via an app. However, it has been observed that the real waiting times are not posted in the app. In fact, WDW rounds the waiting time up to nearest five minute interval. In this paper, we build a simulation model to study the impact of rounding this information and when the information is lagged. We show that rounding or delaying information can result in oscillations in the queue length process. Moreover, increasing the rounding parameter or the delay in information causes oscillations to increase. We also demonstrate that our queueing model can mimic the observed dynamics in the data seen in WDW. Thus, we show the importance of understanding the impact of rounding or delaying information.

Discrete Event Simulation of Appointments Handling at a Children's Hospital Call Center: Lessons Learned from V&V Process / Angelo Pisaniello Jr. (VS Telecom Ltda); Willian Borba da Silva (Itaú Unibanco S.A.); Leonardo Chwif (Escola de Engenharia Mauá, Mauá Institute of Technology); and Wilson Inacio Pereira (Simulate Tecnologia de Simulação)

Validation and Verification (V&V) is one of the most important aspects of the simulation modeling process. During the three stages of V&V (conceptual validation, verification, and operational validation), it is possible to identify inconsistencies in the model's development and, therefore, increase the trust that the model is an adequate representation of reality. The aim of this paper is to demonstrate practical problems and benefits while applying V&V techniques, even if takes a lot of project time, as an indispensable step in guiding the modeler to solving any missed issue. Shortcomings and benefits of V&V techniques application were demonstrated through a case study at a Children's hospital Call Center.

Simulation Study of Dynamic Load Balancing for Processor Sharing Servers with Finite Capacity Under Generalized Halfin-Whitt Regimes / Matias Bonaventura (Universidad de Buenos Aires, ICC-CONICET); Matthieu Jonckheere (Universidad de Buenos Aires, IC-CONICET); and Rodrigo Castro (Universidad de Buenos Aires, ICC-CONICET)

Defining efficient decentralized load balancing schemes exhibiting low memory and communication costs is an important ongoing topic. In particular, characterizing critical regimes where a system optimizes resource usage is uncharted territory. We consider here dynamic balancing schemes in a set of processor sharing servers with finite capacity. Guided by recent results for insensitive load balancing schemes, we applied a modeling and simulation strategy to characterize systematically and extensively several classes of balancing policies under various statistical conditions. We found that there is a class of efficient policies for which a common critical regime can be identified and interpreted as a generalization of the Halfin-Whitt-Jagerman regime for one-server systems. We also study the gap between full and partial information systems, and analyze the performance sensitivity to jobs' size distribution. This study is motivated by the network architecture in the ATLAS experiment at CERN, where load balancing plays a key role.

SIMULATION EDUCATION / R15

Simulation Education Practice
DJ Van der Zee (University of Groningen)

Methodology for the Management of Discrete Event Simulation Projects based on PMBOK®: Action Research in a High-tech Company / Tábata Fernandes Pereira, José Arnaldo Barra Montevechi, and Mona Liza Moura de Oliveira (Federal University of Itajubá); Stewart Robinson (Loughborough University); Amarnath Banerjee (Texas A&M University); and Luiz Felipe Pugliese (Federal University of Itajubá)

Discrete Event Simulation (DES) is a powerful tool for decision making. It has been widely used in different application fields. There are many works investi-

gating the simulation modeling process, but little is found in the literature that considers how to manage a DES project. In this respect, this paper has the objective of proposing a specific methodology for the management of DES projects based on PMBOK®. This was considered to be the methodology that most fits with the requirements of DES. In order to test the approach, PMBOK® was applied in a real simulation project. The methodology was then evaluated by the simulation analysts who provided their feedback on the study.

Bringing Students to Practice: Performing a Real-Life Simulation Study in an Introductory Simulation Course / Niels Martin (Hasselt University)

Business process simulation can support the analysis and improvement of business processes and, hence, is a valuable technique to teach to students. Consequently, introductory simulation courses are included in a multitude of study programs. Besides providing students with theoretical knowledge and getting them acquainted with simulation software, it is also important to let them experience the complexity involved in conducting a simulation study in practice. In this respect, this paper outlines the inclusion of a real-life simulation study in an introductory simulation course. Besides the content of the simulation study, the instructional design, student feedback, company feedback and challenges perceived by the instructor are outlined. Student feedback shows that, even though the project was perceived as highly challenging, conducting the real-life simulation study provided extensive learning opportunities.

Academic/Industry Educational Lab for Simulation-based Test and Evaluation of Autonomous Vehicles / James F. Leathrum, Roland R. Mielke, and Yuzhong Shen (Old Dominion University) and Harry Johnson (Lockheed Martin)

An academic/industry alliance can improve the preparedness of students to enter the workforce. When the alliance is centered around a laboratory providing students real world research and development experience, both partners benefit from the intellectual engagement. This paper discusses the benefits of a collaborative laboratory being developed in support of the modeling and simulation engineering program at Old Dominion University. The laboratory focuses on simulation-based test and evaluation (T&E) of autonomous vehicles, an important economic and social problem. Economically, driverless cars and drone delivery systems are the wave of the future. Socially there are issues of public acceptance of these systems as evident by public reaction to the infrequent, but highly public, accidents involving driverless cars. The laboratory allows academia and industry to address these important problems by improving the T&E of these systems while also improving student skills, giving undergraduate and graduate students an opportunity to participate in research.

SIMULATION OPTIMIZATION / J2

Theoretical Advances in SO
Henry Lam (Columbia University)

Green Simulation Optimization Using Likelihood Ratio Estimators / David J. Eckman (Cornell University) and M. Ben Feng (University of Waterloo)

Green simulation is the reuse of past simulation outputs to enhance the efficiency of current and future simulation experiments. One natural application of green simulation is in the context of simulation optimization, wherein outputs from past iterations in a search can be reused in subsequent iterations. In this article, we draw attention to challenges that arise when green simulation likelihood ratio estimators are naively employed in simulation optimization. In particular, we show that for searches that identify new designs based on past outputs, outputs in different iterations are conditionally dependent, violating one of the assumptions for the validity of the likelihood ratio estimator. As a result, green simulation likelihood ratio estimators of the objective and gradient can become biased. We demonstrate how this conditional dependence and bias can adversely affect the behavior of gradient-based optimization algorithms.

Assessing Solution Quality In Stochastic Optimization Via Bootstrap Aggregating / Henry Lam and Huajie Qian (Columbia University)

We study a statistical method to estimate the optimality gap, as an assessment of the quality, of a given solution for a stochastic optimization using limited data. Our approach is based on bootstrap aggregating the resampled optimal values of sample average approximation (SAA), by connecting these SAA values with the classical notion of symmetric statistics. We discuss how this approach works on general stochastic optimization problems and is statistically

more efficient than some previous methods. We substantiate our findings with several numerical experiments.

Sampling Uncertain Constraints under Parametric Distributions / Henry Lam (Columbia University) and Fengpei Li (fl2412@columbia.edu)

We consider optimization problems with uncertain constraints that need to be satisfied probabilistically. When data are available, a common method to obtain feasible solutions for such problems is to impose sampled constraints, following the so-called scenario generation (SG) approach. However, when the data size is small, the sampled constraints may not support a guarantee on the feasibility of the obtained solution. This paper studies how to leverage parametric information and the power of Monte Carlo simulation to obtain feasible solutions even when the data are not sufficient to support the use of SG. Our approach makes use of a distributionally robust optimization formulation that informs the Monte Carlo sample size needed to achieve our guarantee.

VENDOR TUTORIALS / R4

Arena

Scenario Analysis with Arena Simulation / Tyler DiFrischia (Rockwell Automation)

Arena Simulation Software from Rockwell Automation is used to analyze and compare scenarios to ensure the optimal configuration of business processes. Customers use this tool globally to make informed decisions and avoid wasteful spending. In this session, Rockwell Automation will review how they used Arena Simulation to develop a digital twin, analyze a production line, and cut down on change over times to meet customer demands. During the discussion, Rockwell will also introduce the newest features used to make this powerful simulation.

VENDOR TUTORIALS / R25

Experior / Mozart

Smart SCM Framework with Mozart / Keyhoon Ko (VMS Global, Inc.) and Seungyoung Chung and Byung Hee Kim (VMS Solutions. Co. Ltd)

Accurate production schedule is a key attribute to collaborate among supply chain and meet the due date. Based on current progress using IoT (Internet of Things) technology as well as MES (manufacturing execution system), a simulation-based planning and scheduling system mimics the real manufacturing system and generates reasonable results. Simulation may be a useful tool to solve complex process shedule like semiconductor manufacturing or tons of sub-parts such as ship building and offshore industry. MOZART has been implemented in semiconductor, display panel, and tire industries as a planning and scheduling system. It covers weekly planning (Master Plan: MP), daily planning (Factory Plan: FP), and real time scheduling for these double-digit-day cycle time product manufacturing. MOZART extended the coverage to meet offshore project whose cycle time is several hundreds of days.

Using Modern 3D Modelling throughout the Lifecycle of Automation Systems with Experior / Bent Aksel Jørgensen (Xcelgo)

In the manufacturing and logistics industries, the use of 3D models of automation systems is becoming increasingly relevant. Traditionally, these industries only used simple simulations to support concept modelling in the early design phase as well as classic simulation in the decision-making process, but modern technology has given rise to the development of 3D modeling in new and exciting directions. Important game changers are virtual commissioning technologies and versatile 3D modelling software platforms that allows for custom 3D modelling tools and integration with company workflow. These technologies paves the way for control software testing prior to commissioning, realistic operator training, safe modifications and optimization during operation as well as handy retrofitting and refurbishment. This presentation presents the new modelling approaches and tools applied to support each stage of an automations system's lifecycle, and the System Lifecycle Management approach to integrate company workflow with 3D modelling.

Tuesday 11:30a.m.-12:15p.m.

WORLD CAFÉ / CONGRESS FOYER

World Café - II
Margaret Loper (Georgia Tech Research Institute)

Participants will discuss identified topics at different tables over lunch. New topics may be included that may have been generated during World Café - I discussion the previous day. Each table will have a host, who will introduce the topic and facilitate the discussion. Ideas, questions, and concerns that are generated will be captured, enabling participants to pool their ideas and examine issues from various angles.

Tuesday 12:20p.m.-1:20p.m.

TITANS OF SIMULATION / CONGRESS HALL

Titan Talk: Russell Cheng
Sanjay Jain (The George Washington University)

Creating a Real Impression: Visual Statistical Analysis / Russell Cheng (University of Southampton)

Many powerful statistical methods available for studying simulation output are under-appreciated and consequently under-used, because they are considered to be hard-to-understand, arcanely mathematical, and hard to implement. Such methods can invariably be implemented using data-driven resampling methods, making their underlying rationale quite transparent. There is little need for much formal mathematics, and what there is can be made visually obvious, with method and results explained and presented using figures and graphs, often with dynamic animation. This approach in studying simulation output will be illustrated by a number of examples drawn from simulation studies and real applications. A bonus of the approach is that it is quite easy to create one's own 'bespoke' method of analysis tailored to a particular problem. Such examples will be presented and analyzed in 'real-time' in the talk itself, enabling the results to be immediately displayed.

RUSSELL CHENG is Emeritus Professor at Southampton having been Professor of Operational Research and Head of the OR Group from 1999 to 2007, in the School of Mathematics. He obtained an MA from Cambridge University, and a PhD from the University of Bath. He was previously Deputy Director of the Institute of Mathematics and Statistics and Head of Management Science at the University of Kent at Canterbury. His research interests have been in: Design and Analysis of Simulation Experiments, Non-standard Parametric Estimation, Computer Generated Graphics, Optimal Control of Industrial Processes, and Marine Simulation. He is a former Fellow of the Royal Statistical Society, a Fellow of the Institute of Mathematics and Its Applications, and is a past Chairman of the United Kingdom Simulation Society. He is a past Board Member of EUROSIM, the Federation of Simulation Societies in Europe. He has been an Associate Editor of Management Science and was Joint Editor of the IMA Journal of Mathematics Applied in Business and Industry, and then founding Editor of the IMA Journal of Management Mathematics for which he received, in 2008, the IMA's Certificate of Service. He was Council member of the INFORMS Simulation Society (2006-08) and received the Society's Distinguished Service Award in 2007 and Lifetime Professional Achievement Award in 2016. He was the Consultant Research Director of Norcontrol Imaging Systems Ltd, a subsidiary of Norcontrol a.s., the largest manufacturer of marine simulators world-wide. He is author of the book Non-Standard Parametric Statistical Inference published in 2017 by Oxford University Press. He is currently a course lecturer in the UK's National Taught Course Centre in Operational Research (NATCOR) which delivers nationwide residential courses to UK research students in OR and Management Science.

Tuesday 1:30p.m.-3:00p.m.

ADVANCED TUTORIALS / R23

Collective Adaptive System Modeling
Adelinde Uhrmacher (University of Rostock)

Statistical Analysis of CARMA Models: An Advanced Tutorial / Vashti Galpin (University of Edinburgh), Anastasis Georgoulas (UCL), Michele Loreti (University of Camerino), and Andrea Vandin (Technical University of Denmark)

CARMA (Collective Adaptive Resource-sharing Markovian Agents) is a process-algebra-based quantitative language developed for the modeling of collective adaptive systems. A CARMA model consists of an environment in which a collective of components with attribute stores interact via unicast and broadcast communication, providing a rich modeling formalism. The semantics of a CARMA model are given by a continuous-time Markov chain which can be simulated using the CARMA Eclipse Plug-in. Furthermore, statistical model checking can be applied to the trajectories generated through simulation using the MultiVeStA tool. This advanced tutorial will introduce some of the theory behind CARMA and MultiVeStA as well as demonstrate its application to collective adaptive system modeling.

AGENT-BASED SIMULATION / R5

Emergency and Safety
Martijn Mes (University of Twente)

Emergency Management in China: A Survey of System, Agent-based Modeling, and Recommendation / Jing Yang (Sunny) Xi and Wai Kin (Victor) Chan (Tsinghua University, TBSI)

Disasters, whether natural or man-made, hinder the security and stability of societies worldwide. People in disaster prone areas live in constant fear, not knowing when and where disasters will strike. Therefore, it is critical to design emergency management systems and contingency plans to prepare for the worst. While a great number of plans have been proposed around the globe, the geographical properties and cultural differences between disaster sites significantly affect their efficiencies. This paper surveys existing literature on emergency management in China and summarizes different evacuation models, in particular, agent-based models and other models. We identify four major issues in the emergency management system in China and provide recommendations and guidelines for addressing these issues. To exemplify the implementation of these recommendations, we provide an example based on a statistical model and an agent-based simulation model to substantiate the development of the emergency management system in China.

Modeling Safest and Optimal Emergency Evacuation Plan for Large-Scale Pedestrians Environments / Muhammad Haris, Imran Mahmood, Maryam Badar, and Muhammad Saad Qaisar Alvi (National University of Sciences and Technology)

Large-scale events are always vulnerable to natural disasters and man-made chaos which poses great threat to crowd safety. Such events need an appropriate evacuation plan to alleviate the risk of causalities. We propose a modeling framework for large-scale evacuation of pedestrians during emergency situation. Proposed framework presents optimal and safest path evacuation for a hypothetical large-scale crowd scenario. The main aim is to provide the safest and nearest evacuation path because during disastrous situations there is possibility of exit gate blockade and directions of evacuees may have to be changed at run time. For this purpose run time diversions are given to evacuees to ensure their quick and safest exit. In this work, different evacuation algorithms are implemented and compared to determine the optimal solution in terms of evacuation time and crowd safety. The recommended framework incorporates Anylogic simulation environment to design complex spatial environment for large-scale pedestrians as agents.

Multi-Agent Based Simulation of Elderly Egress Process and Fall Accident in Senior Apartment Buildings / Xiaojie Du, Yuan Chen, Ahmed Bouferguene, and Mohamed Al-Hussein (University of Alberta)

A means of egress from buildings is a critical aspect of building design and an important part of building fire regulations. However, elderly evacuees are often

overlooked, being regarded as part of the average population, thereby ignoring the limitations elderly people may have. The computational egress model is a useful tool to evaluate postulated "what-if" scenarios, aiming to predict building egress performance under these designated scenarios. This paper first applies Multi-agent Based Simulation (MABS) supported by NetLogo to simulate the evacuation scenarios where evacuees are all elderly people, then statistical analysis is utilized to interpret results, and comparative analysis is conducted to offer some suggestions for egress design and crowd management.

ANALYSIS METHODOLOGY / CONGRESS HALL

Rare-Event Simulation - I
Marvin K. Nakayama (New Jersey Institute of Technology)

Designing Importance Samplers to Simulate Machine Learning Predictors via Optimization / Zhiyuan Huang (University of Michigan), Henry Lam (Columbia University), and Ding Zhao (Carnegie Mellon University)

We study the problem of designing good importance sampling (IS) schemes to simulate the probability that a sophisticated predictor, built for instance from an off-the-shelf machine learning model, gives a prediction that exceeds a large threshold. This problem is motivated as a step towards building good learning algorithms that takes into account the extremal risks of the prediction. We provide a framework to design IS for two common machine learning models, namely random forest and a basic neural network. Our approach utilizes some available mathematical programming formulations to optimize over these models and a simple "cutting plane" idea to look for dominant points under Gaussian input distributions.

Simulation-based Assessment of the Stationary Tail Distribution of a Stochastic Differential Equation / Krzysztof Bisewski and Daan Crommelin (Centrum Wiskunde & Informatica) and Michel Mandjes (University of Amsterdam)

A commonly used approach to analyzing stochastic differential equations (SDEs) relies on performing Monte Carlo simulation with a discrete-time counterpart. In this paper we study the impact of such a time-discretization when assessing the stationary tail distribution. For a family of semi-implicit Euler discretization schemes with time-step $h>0$, we quantify the relative error due to the discretization, as a function of h and the exceedance level x. By studying the existence of certain (polynomial and exponential) moments, using a sequence of prototypical examples, we demonstrate that this error may tend to 0 or infinity. The results show that the original shape of the tail can be heavily affected by the discretization. The cases studied indicate that one has to be very careful when estimating the stationary tail distribution using Euler discretization schemes.

Monte Carlo Estimation of Economic Capital / Zachary T. Kaplan, Yajuan Li, and Marvin K. Nakayama (New Jersey Institute of Technology)

Economic capital (EC) is a risk measure that has been used by financial firms to help determine capital levels to hold to protect (with high probability) against large unexpected losses of credit portfolios. Given a stochastic model for a portfolio's loss over a given time horizon, the EC is defined as the difference between a quantile and the mean of the loss distribution. We describe Monte Carlo methods for estimating the EC. We apply measure-specific importance sampling to separately estimate the two components of the EC, which can lead to much smaller variance than when estimating both terms simultaneously. We provide Bahadur-type representations for our estimators of the EC, which we further exploit to establish central limit theorems and asymptotically valid confidence intervals. We present numerical results for a simple model to demonstrate the effectiveness of our approaches.

CASE STUDIES / R4

Simulation Techniques
Ferdinand Bär (FZI)

Implementation of a Data-Centric Symbiotic Simulation Technique for Enhancing Ford PTME Throughput Simulation Processes / Emmanuel Chiroma and Michael Higgins (Ford Motor Company) and Andy Chandler (Lanner)

With the ever-increasing importance of simulation in supporting decision making, strategic planning and operations within a fast paced business environment, traditional simulation has lagged behind, constrained as it is by long lead times

for model update and validation. Symbiotic simulation has emerged as a solution, enabling a timely response to abrupt changes in the physical system. In this presentation, we introduce the implementation of symbiotic simulation as part of an overhaul of Ford Power Train Manufacturing Engineering throughput simulation methodology and discuss challenges, opportunities and lessons learned.

S-Flow: Methodology of Applying Discrete-Event Simulation / Nicholas B. Allen (Honda of America Manufacturing, Inc.)

S-Flow, or Simulation-Flow, is the name of the methodology for utilizing discrete-event simulation (DES) that has evolved from over 20 years of use in automotive manufacturing. This process has been refined to address typical pitfalls of applying DES and to ensure acceptance by non-experts. The methodology walks the simulation engineer through stages of project planning, model planning, data analysis, model development, model verification and validation, scenario testing, results analysis, and project reflections. Each stage is explored in depth to show the potential pitfalls that can be avoided. Complete and consistent usage of the methodology promotes awareness and approval of DES analysis as well as the opportunity to further improve the S-Flow methodology.

An Early Phase Case of VSM and Discrete Event Simulations / Martin Kurdve (Chalmers University of Technology, Swerea IVF AB) and Daniel Malm (ValueAdd Solutions)

This paper use a case study to investigate the process analysis methods using value stream mapping and discrete event simulation in early phases change decision making. The case study discuss the practical situation for the modeler. The output of each tool and the combination is evaluated with the modelling effort in mind. The result shows that it may be preferable to analyse issues like static bottlenecks and average capacity with value stream mapping while for dynamic issues discrete event simulation may be necessary. For industrial application purposes it is proposed to build the models simultaneously and to take time to do the proper static analysis before doing the dynamic analysis in order to understand the dynamic results.

COMPLEX, INTELLIGENT, ADAPTIVE AND AUTONOMOUS SYSTEMS / R22

Performance/Evaluation
Rodrigo De la Fuente (University of Concepcion)

Comparison of Data Analytics Approaches using Simulation / Sanjay Jain (The George Washington University), Anantha Narayanan (University of Maryland), and Yung-Tsun Tina Lee (National Institute of Standards and Technology)

Manufacturers need to quickly estimate cycle times for incoming orders for promising delivery dates. This can be achieved by using data analytics (DA) / machine learning (ML) approaches. Selecting the right DA/ML approach for an application is rather complex. Obtaining sufficient and right type of data for evaluating these approaches is a challenge. Simulation models can support this process by generating synthetic data. Simulation models can also be used to validate DA models by generating new data under varying conditions. This can help in the evaluation of alternative DA approaches across expected range of operational scenarios. This paper reports on use of simulation to select an approach to support the order promising function in manufacturing. Two DA approaches, Neural Networks and Gaussian Process Regression, are evaluated using data generated by a manufacturing simulation model. The applicability of the two approaches is discussed in the context of the selected application.

Distributed and Optimal Resilient Planning of Large-Scale Interdependent Critical Infrastructures / Linan Huang, Juntao Chen, and Quanyan Zhu (New York University)

The complex interconnections between various critical infrastructure sectors make the system of systems (SoS) vulnerable to failures and highlight the importance of robustness and resilience. To this end, we first establish holistic probabilistic networks to model the interdependencies between infrastructure components. To capture the underlying failure and recovery dynamics, we further propose a Markov decision processes (MDP) model in which the response policy determines a long-term performance. To address the challenge of a large dimensionality, we exploit the sparsity of the network interconnections and solve an approximate linear program by the variable elimination, which leads to a distributed control policy under mild assumptions. Finally, we use a

case study of the interdependent power and subway systems to corroborate the results and show that the optimal resilience resource planning and allocation can reduce the failure probability and mitigate the impact of failures caused by natural or artificial disasters.

Enabling Intelligent Processes in Simulation Utilizing the TensorFlow Deep Learning Resources / Rodrigo Andres De la Fuente (University of Concepcion), Raymond Lester Smith III (East Carolina University), and Ignacio Erazo (University of Concepcion)

Availability of large data sets and increased computing performance have contributed to many improvements in productivity and decision making. Simulation can exploit these by incorporating data mining capabilities, such as machine learning, in the modeling and analysis process. This paper demonstrates the integration of discrete event simulation with a deep learning resource, known as TensorFlow, to enable intelligent decision making in the form of smart processes. A bank credit approval process is modeled using these smart processes to evaluate customer credit worthiness based on 20 reported features. Comparison of three models is made where credit worthiness is (1) known, (2) randomly assigned, or (3) evaluated based on customer features. Additionally, the experiment compares results under conditions where the process is perturbed by an unexpected surge in customer arrivals. The presented models and results demonstrate the feasibility of enabling smart processes in discrete event simulation software and the improved decision-making fidelity.

CYBER-PHYSICAL SYSTEMS / R11

Adaptive and Embedded CPS
Nikos Arechiga (Toyota Research Institute)

DEVS-over-ROS (DoveR): A Framework for Simulation-driven Embedded Control of Robotic Systems Based on Model Continuity / Ezequiel Pecker Marcosig, Juan Ignacio Giribet, and Rodrigo Castro (UBA, CONICET)

Designing hybrid controllers for cyber-physical systems raises the need to interact with embedded platforms, robotic applications being a paradigmatic example. This can become a difficult, time consuming and error-prone task for non-specialists as it demands for background on low-level software/hardware interfaces often falling beyond the scope of control designers. We propose a simulation-driven methodology and tool for designing hybrid controllers based on a model continuity approach. The simulation model of a controller should evolve transparently from a desktop-based mocking up environment until its final embedded target without the need of intermediate adaptations. DEVS-over-ROS relies on the DEVS framework for robust modeling and real-time simulation of hybrid controllers, and on the ROS middleware for flexible abstraction of software/hardware interfaces for sensors and actuators. We successfully tested DoveR in a case study where a custom-made crafted robotic system is built concurrently with the design of its controller.

A Predictive Self-configuring Simulator for Online Media / Shuochao Yao and Yifan Hao (UIUC); James Flamino (RPI); Dongxin Liu, Shengzhong Liu, Huajie Shao, Mouna Bamba, Jiahao Wu, and Tarek Abdelzaher (UIUC); and Boleslaw Szymanski (RPI)

This paper describes the design, implementation, and early experiences with a novel agent-based simulator of online media streams, developed under DARPA's SocialSim Program to extract and predict trends in information dissemination on online media. A hallmark of the simulator is its self-configuring property. Instead of requiring initial set-up, the input to the simulator constitutes data traces collected from the medium to be simulated. The simulator automatically learns from the data such elements as the number of agents involved, the number of objects involved, and the rate of introduction of new agents and objects. It also develops behavior models of simulated agents and objects, and their dependencies. These models are then used to run simulations allowing for future extrapolations and "what if" analyses. Results are presented on using this system to simulate GitHub transactions. They show good performance in terms of both simulation accuracy and overhead.

Data-Centric Cyber-Physical Systems Design with SmartData / Antonio Augusto Frohlich and Davi Resner (UFSC)

Timeliness is a fundamental property of Cyber-Physical Systems that has been intensively investigated within the scope of real-time and critical systems. The advent of the Internet of Things, however, brings an intense communication

flow between devices and the Internet. In this scenario, modeling time requirements in terms of data, rather than the tasks that manipulate them, may be advantageous as a data-centric design can promptly encompass other first-order requirements, such as geolocation, security, and trustworthiness. In this paper, we propose a strategy to design complex CPSs by modeling their data using the SmartData construct, which, besides encompassing means to handle the aforementioned requirements, also defines the concept of data expiry to guide scheduling decisions. With SmartData, local tasks are scheduled to produce the freshest data and to manipulate them before expiration. Likewise, network packets are scheduled prioritizing data whose expiry is close. We validate the strategy through simulations using Castalia.

HEALTHCARE APPLICATIONS / R12

Outpatient Clinic Design
Bjorn Berg (University of Minnesota)

Using Simulation to Design a WorkLife Integrated Practice Unit / Douglas J. Morrice, Jonathan F. Bard, Harshit Mehta, Swarup Sahoo, Natesh B. Arunachalam, and Prashanth Venkatraman (The University of Texas at Austin)

Fragmentation is a common problem in the United States healthcare delivery system. For patients with complex medical conditions requiring multiple providers, this problem is particularly perplexing. One solution being developed, called an Integrated Practice Unit (IPU), involves a co-located multidisciplinary team of providers addressing a patient's medical condition over a full care cycle. In this paper, we use simulation to design a WorkLife IPU that treats medical issues arising in the workplace from minor illnesses to acute non-urgent injuries. More specifically, we determine a patient appointment schedule and the number of resources required to achieve patient throughput, clinic closing time, and patient waiting time targets set by the IPU management.

A Simulation Framework for the Design and Analysis of Healthcare Clinics / Jason D. Ceresoli and Michael E. Kuhl (Rochester Institute of Technology)

The treatment of patients in outpatient healthcare clinics is a continually growing trend as technology improves and recovery benefits are recognized. In this paper, we focus on the operational aspects of clinics that will impact clinic design decisions relative to productivity, efficiency, and quality of patient care. We develop a generalized Healthcare Clinic Design Simulator (HCD-Sim) to study the dynamic system behavior and to analyze alternative outpatient healthcare clinic designs. Our simulation framework is designed to have a data-driven structure that is able to represent a large class of outpatient healthcare clinics through the specification of clinic data relative to patient flows, work flows, and resource requirements. We describe our methodology and demonstrate the capabilities of experimentation utilizing the simulation framework.

Use of Simulation to Evaluate Resource Assignment Policies in a Multidisciplinary Outpatient Clinic / Bjorn Berg, Grant Longley, and Jordan Dunitz (University of Minnesota)

Advances in facility design and technology are leading to novel uses of healthcare delivery space including flexible and shared clinical space increasing collaboration and communication in multidisciplinary care settings. With new outpatient care delivery facilities and plans emerging, the need to evaluate how flexible and shared resources are assigned arises. We present a discrete-event simulation model based on the daily operations of an outpatient clinic where multiple specialties share resources including support staff, exam rooms, and ancillary providers. Being a new clinical space, the primary objective is to design resource assignment and staffing policies which maximize the use of the new facility. While resource utilization is the primary objective, the simulation model results and analysis incorporate other competing performance criteria including patient waiting, provider idleness, and clinic length of day. Results are presented based on a multidisciplinary clinic at the University of Minnesota.

HOMELAND SECURITY ENTERPRISE / R17

Advanced Simulation Systems
Pär Daléus (Swedish Defence University)

Simedis 2.0: On the Road Toward a Comprehensive Mass Casualty Incident Medical Management Simulator / Ruben De Rouck (Vrije Universiteit Brussel), Selma Koghee (Royal Military Academy), Michel Debacker (Vrije Universiteit Brussel), Filip Van Utterbeeck (Royal Military Academy), Erwin Dhondt (BEL Defense), and Ives Hubloue (Vrije Universiteit Brussel)

Mass casualty incidents still cause a huge amount of deaths and injuries in the twenty-first century. Research on these events is challenging due to inherent ethical and logistical difficulties. Computer simulation models can overcome these difficulties, and offer evidence on which to base policy and decisions. In this paper a discrete event simulation model is described, designed to analyze prehospital policies and commonly made decisions. We studied an airplane crash scenario and analyzed mortality as a primary and treatment and transport times as secondary outcome measures. We implemented resource dispatching, search and rescue at the disaster site, triage, treatment and evacuation of victims to healthcare facilities. Overall we conclude that for this scenario - where treatment capacity is sufficient - the best outcome for victims can be achieved by the combination of triage and quick distribution of victims to regional hospitals.

Use of Modeling and Simulation in Emergency Preparedness and Response: Standard Unified Modeling, Mapping, Integration Toolkit (SUMMIT) / Ajmal Aziz (DHS), Kamran Atri (Constellation Software Engineering), and Jalal Mapar (DHS)

The Standard Unified Modeling, Mapping, and Integration Toolkit (SUMMIT) is an innovative simulation platform that enables users to discover/reuse models and execute case studies to analyze emergency events. SUMMIT accelerates "what-if" analysis of disaster scenarios and improves the planning and execution of exercises. The key features of SUMMIT are in reuse of models that have been integrated into the model library, an interface that helps non-programmers to compose scenarios, ability to rapidly test and compare disaster scenarios from one location to another. SUMMIT contains a number of case files that constitute synthetic data for analysis of response and recovery operations, trends, impacts, and risks. SUMMIT supports the National Preparedness System as described in the Presidential Policy Directive 8 (PPD-8) and has been transitioned into an operational environment for use in training, exercise, threat/hazard risk assessment, resilience, and other preparedness activities.

Agent-based Modeling for Casualty Rate Assessment of Large Event Active Shooter Incidents / Jae Yong Lee and J. Eric Dietz (Purdue University, Purdue Homeland Security Institute) and Kayla Ostrowski (Purdue University)

The 1999 Columbine attack changed police response to the active shooter incidents (ASI) by the public and first responder's tactics and training. With FBI data suggesting ASI events increasing, this study offers an AnyLogic models to understand mitigation actions such as Run.Hide.Fight. Our model represents a general densely populated area, such as public transportation terminal or indoor arena. Model agents include civilians, police, and shooter agents interact with the following parameters: civilian evacuation time, the response of police, firearm discharge by the shooter and police. The casualty rates vary from 85 to 1 causalities when the shooter's rate of discharge was 1 to 60 seconds, respectively. The model as developed was shown to provide a method to evaluate and compare actions such as adequacy of training, introduction of technology into public buildings and the general design of public spaces to reduce the impact of ASI events.

HYBRID SIMULATION / R6

Hybrid Simulation in Healthcare
Sally Brailsford (University of Southampton)

A Multi-Method Scheduling Framework for Medical Staff / Wael Rashwan (Dublin Institute of Technology (DIT)), John Fowler (Arizona State University), and Amr Arisha (Dublin Institute of Technology (DIT))

Hospital planning teams are always concerned with optimizing staffing and scheduling decisions in order to improve hospital performance, patient experience, and staff satisfaction. A multi-method approach including data analytics,

modeling and simulation, machine learning, and optimization is proposed to provide a framework for smart and applicable solutions for staffing and shift scheduling. Factors regarding patients, staff, and hospitals are considered in the decision. This framework is piloted using the Emergency Department(ED) of a leading university hospital in Dublin. The optimized base staffing patterns and shift schedules actively contributed to solving ED overcrowding problem and reduced the average waiting time for patients by 43% compared to the current waiting time of discharged patients. The reduction was achieved by optimizing the staffing level and then determining the shift schedule that minimized the understaffing and overstaffing of the personnel need to meet patient demand.

The Impact of Demographic Trends on Future Hospital Demand Based on a Hybrid Simulation Model / Bożena Mielczarek, Jacek Zabawa, and Wiesław Dobrowolski (Wrocław University of Science and Technology)

This study examines how changes in the age structure of Polish population inhabiting an administrative region, the Wrocław Region (WR), will affect the demand for healthcare services during the period 2016–2017. We constructed a hybrid simulation model that operates on two submodels. The system dynamics submodel simulates the evolution of population using an aging chain approach to forecast the number of individuals belonging to the respective age-gender cohorts. On the other hand, the discrete event submodel forecasts the number of patients in and number of treatments generated by the respective age-groups. We found that the effect of the WR population growth on the total healthcare demand will be small; however, it will have a larger impact on the number of elderly patients and the volume of more expensive services delivered in WR hospitals.

A Hybrid Discrete Event Agent Based Overdue Pregnancy Outpatient Clinic Simulation Model / Joe Viana, Tone Breines Simonsen, Kari Flo, and Fredrik A. Dahl (Akershus University Hospital)

This paper provides an overview of a hybrid, discrete event simulation (DES) agent based model (ABM), simulation model of the overdue pregnancy outpatient clinic at the Obstetrics department of Akershus University Hospital, Norway. The model is being developed in collaboration with clinic staff. The purpose of the model is to better plan resources (e.g. staffing) to improve patient flow at the outpatient clinic given the uncertainty associated with demand. The uncertainty is due to an increase in the size of the hospital's catchment area, changes to overdue pregnancy guidelines in Norway and that women can give birth before their appointments. The ABM model component represents the human parts of the system, the women and the clinic staff. The DES component represents the outpatient clinic's physical location and processes/pathways that operate within it. The technicalities of the model are presented along with some illustrative results.

INTRODUCTORY TUTORIALS / R31

A Tutorial on Designing and Conducting Simulation Experiments
Naoum Tsioptsias (Loughborough University)

Work Smarter, Not Harder: A Tutorial on Designing and Conducting Simulation Experiments / Susan M. Sanchez and Paul J. Sánchez (Naval Postgraduate School) and Hong Wan (Purdue University)

Simulation models are integral to modern scientific research, national defense, industry and manufacturing, and in public policy debates. These models tend to be extremely complex, often with thousands of factors and many sources of uncertainty. To understand the impact of these factors and their interactions on model outcomes requires efficient, high-dimensional design of experiments. Unfortunately, all too often, many large-scale simulation models continue to be explored in ad hoc ways. This suggests that more simulation researchers and practitioners need to be aware of the power of designed experiments in order to get the most from their simulation studies. In this tutorial, we demonstrate the basic concepts important for designing and conducting simulation experiments, and provide references to other resources for those wishing to learn more. This tutorial (an update of previous WSC tutorials) will prepare you to make your next simulation study a simulation experiment.

LOGISTICS, SCM, TRANSPORTATION / R21

Simheuristics for Logistics, SCM and Transportation - I
Carles Serrat (Universitat Politècnica de Catalunya-BarcelonaTECH)

Integrating Biased-randomized GRASP with Monte Carlo Simulation for Solving the Vehicle Routing Problem with Stochastic Demands / Paola Festa and Tommaso Pastore (University of Naples Federico II) and Daniele Ferone, Angel A. Juan, and Christopher Bayliss (Universitat Oberta de Catalunya)

Few problems in Operations Research are regarded as highly as the Vehicle Routing Problem (VRP). Its relevance within management and industrial settings has led to the variants of this problem being widely studied by the scientific community. With the aim of solving the VRP with stochastic demands we analyze an extension of the classical GRASP metaheuristic. This work hybridizes a biased-randomized GRASP (BR-GRASP) with a two-stage Monte Carlo simulation which has the ability to attain robust and competitive solutions. In the first stage, a promising set of local optimum solutions is identified based on a short simulation evaluation. In the second stage, the promising solutions are tested for reliability using a larger number of simulation runs. The most reliable solution is the final solution. Experiment results are provided that demonstrate that the proposed integrated algorithm leads to higher quality solutions than the equivalent approach without such an integration.

Simulation-based Autonomous Algorithm Selection for Dynamic Vehicle Routing Problems with the Help of Supervised Learning Methods / Thomas Mayer, Tobias Uhlig, and Oliver Rose (Universität der Bundeswehr München)

Multi-constrained Vehicle Routing Problems are gaining steadily in importance. Especially, the dynamic version of the problem has become more emphasis due to modern service requirements, such as short-term or express delivery. With a growing number of dedicated solution approaches for these problems, we investigate a simulation-based supervised learning approach to determine the suitability of a particular algorithm from a set of algorithms for a given dynamic problem instance based on a variety of its characteristics. This decision is known as the Algorithm Selection Problem. We explore the performance space for Greedy and Re-planning algorithms for different dynamic problem instances by simulation and an evolutionary algorithm. For the algorithm selection we test several problem features in combination with two supervised machine learning techniques. The applicability of our approach is demonstrated in a use case for autonomous algorithm selection for Dynamic Vehicle Routing Problem instances.

Distribution Planning in a Weather-dependent Scenario with Stochastic Travel Times: A Simheuristic Approach / Alejandro Estrada-Moreno (Open University of Catalonia), Carles Serrat (Universitat Politècnica de Catalunya-BarcelonaTECH), María Nogal (Trinity College Dublin), and Marta Cavero-Lázaro and Angel A. Juan (Open University of Catalonia)

In real-life logistics, distribution plans might be affected by weather conditions (rain, snow, and fog), since they might have a significant effect on traveling times and, therefore, on total distribution costs. In this paper, the distribution problem is modeled as a multi-depot vehicle routing problem with stochastic traveling times. These traveling times are not only stochastic in nature but the specific probability distribution used to model them depends on the particular weather conditions on the delivery day. In order to solve the aforementioned problem, a simheuristic approach combining simulation within a biased-randomized heuristic framework is proposed. As the computational experiments will show, our simulation-optimization algorithm is able to provide high-quality solutions to this NP-hard problem in short computing times even for large-scale instances. From a managerial perspective, such a tool can be very useful in practical applications since it helps to increase the efficiency of the logistics and transportation operations.

MANUFACTURING APPLICATIONS / R2

Production Planning
Thomas Felberbauer (St. Pölten University of Applied Sciences)

Agent-based Self-organization Versus Central Production Planning / Torsten Munkelt and Martin Krockert (Dresden University of Applied Sciences)

Industry 4.0, a part of the German high tech strategy, prefers self-organization in production over central production planning for the sake of greater flexibility, faster response to disruptions and to deviations, and less effort. Current planning systems usually plan centrally. We developed a universal self-organizing production and empirically compared its performance to a centrally planned production. The self-organizing production is based upon agents. For better comprehensibility, we additionally implemented central planning. The results of self-organization in production are promising in relation to central planning; especially when disruptions and deviations occur.

A Multi-level Modeling Approach for Simulation-based Capacity Planning and Scheduling of Aircraft Maintenance Projects / Christian Fabig (Technische Universität Dresden) and Elias Winter (Saxony Media Solutions GmbH)

The aim of this contribution is to provide a modeling approach for multi-project manufacturing. Existing approaches for capacity planning and detailed scheduling in those complex environments are using separate models that are linked by instruction and feedback slopes. In contrast, we include multiple levels hierarchically into one simulation model. Thus, the possibilities to propagate restrictions such as precedence dependencies and starting times from gross to detailed levels in a consistent manner are established. The approach is implemented in Java, extending the modeling capabilities of a simulation-based optimization framework. A real-life application to project-oriented aircraft maintenance is presented to highlight the practicality and efficiency of the integrated model for simulation-based capacity planning using work packages as well as detailed scheduling using activities of work plans.

Modeling and Simulation for the Joint Maintenance-inventory Optimization of Production Systems / Farhad Zahedi-Hosseini (University of Salford)

Simulation methodologies are developed to model the joint optimization of preventive maintenance and spare part inventory for a specific industrial plant under different production configurations. First, spare part provision for a single-line system is considered, with the assumption that the demand is driven by maintenance requirements. The results indicate that a periodic review policy with replenishment as frequent as inspection is cost-optimal. Second, the joint optimization model for a multi-line (parallel) system is developed. It is found that a just-in-time review policy with inspection as frequent as replenishment produces the lowest cost policy. In this latter case, an implication of the proposed methodology is that, where mathematical modeling is intractable, or the use of certain assumptions make them impractical, simulation modeling is an appropriate solution tool. Under both production settings, the long-run average cost per unit time is used as the optimality criterion for the comparison of several policies.

MASM / R14

Scheduling and Dispatching Applications
Marcel Stehli (Globalfoundries)

A Mathematical Model for the External Scheduling of a Cluster Tool Workstation / Gottfried Nieke (TU Dresden), Marcel Stehli and Steffen Kalisch (GLOBALFOUNDRIES Inc.), and Christian Maleck and Karlheinz Bock (TU Dresden)

Cluster tools are closed mini production environments that are especially used in the semiconductor industry. They consist of multiple processing chambers. In contrast to single processing tools they can handle multiple lots with different process characteristics at the same time. The major challenge for scheduling cluster tools is the hard to predict process times of even comparable lots as they strongly depend on a changing product mix over the tool. In this paper a mathematical model for the external scheduling of a cluster tool workstation is presented. The goal is to minimize the weighted cycle time by accounting for the changing cycle times of each lot. A MIP model assigns lots to tools of a workstation and determines for each lot the chambers, which are used during the processing steps inside the cluster tool. Finally the developed method is compared with a simulation that uses dispatching strategies.

A Framework for Performance Analysis of Dispatching Rules in Manufacturing Systems / Jehun Lee, Young Kim, Jun Kim, Yun-Bae Kim, and Hyun-Jung Kim (Sungkyunkwan University) and Byung-Hee Kim and Gu-Hwan Chung (VMS Solutions)

Most manufacturing systems in which jobs arrive dynamically and their processing times have variations use dispatching rules to obtain production schedules. In LCD manufacturing, several dispatching rules that reflect the knowledge of the fab operator have been developed and prioritized to select a unique job for processing on a machine. However, engineers rank the dispatching rules based on their experiences without any systematic analysis method. Hence, there is a great need for a tool that can analyze how the order of dispatching rules affect the key performance indicators (KPIs) of schedules. Therefore, we provide a framework for the performance analysis of dispatching rules so that engineers can examine the KPIs for a given order of dispatching rules and find the best order of dispatching rules.

A Study on the Integration of Complex Machines in Complex Job Shop Scheduling / Karim Tamssaouet and Stephane Dauzère-Pérès (Mines Saint-Etienne), Sebastian Knopp (AIT Austrian Institute of Technology), Claude Yugma (Mines Saint-Etienne), and Jacques Pinaton (STMicroelectronics Rousset)

In this paper, we study the problem of considering the internal behavior of complex machines when solving complex job-shop scheduling problems encountered in semiconductor manufacturing. The scheduling problem in the diffusion area is presented, and the complex structures and behaviors of the different machine types in this area are described. Previous related research is reviewed, and our approach to consider the complexity of these machines with batching constraints when scheduling the diffusion area is described. The main part of the paper presents and discusses numerical experiments on industrial instances to show the benefit of choosing a suitable modeling for complex machines.

MODELING METHODOLOGY / R26

Dynamic Data Driven Application Systems
Dong Jin (Illinois Institute of Technology)

Energy Efficient Middleware for Dynamic Data Driven Application Systems / Aradhya Biswas, Michael Hunter, and Richard Fujimoto (Georgia Institute of Technology)

Middleware is required to support and interface multi-modal Dynamic Data Driven Application Systems (DDDAS) with back-end and other computing facilities. Middleware is also needed to support distributed simulations and emulations needed in earlier phases of system development. This work describes the Green Runtime Infrastructure (G-RTI), an energy-efficient client server based middleware developed to support distributed DDDAS simulation, emulation and deployment. G-RTI eases and accelerates the development and testing of multi-modal studies, testbeds and DDDAS systems. It serves as a platform for research in energy reduction techniques for middleware services. The services implemented by G-RTI are described and results of benchmarking studies are reported. Its application is demonstrated through a use-case for an end-to-end implementation of a connected vehicle application. G-RTI is open source.

Just-In-Time Parallel Simulation / Christopher Hannon (Illinois Institute of Technology), Nandakishore Santhi and Stephan Eidenbenz (Los Alamos National Laboratory), Jason Liu (Florida International University), and Dong Jin (Illinois Institute of Technology)

Due to the evolution of programming languages, interpreted languages have gained widespread use in scientific and research computing. Interpreted languages excel at being portable, easy to use, and fast in prototyping than their ahead-of-time (AOT) counterparts, including C, C++, and Fortran. While traditionally considered as slow to execute, advancements in Just-in-Time (JIT) compilation techniques have significantly improved the execution speed of interpreted languages and in some cases outperformed AOT languages. In this paper, we explore some challenges and design strategies in developing a high performance parallel discrete event simulation engine, called Simian, written with interpreted languages with JIT capabilities, including Python, Lua, and Javascript. Our results show that Simian with JIT performs similarly to AOT simulators, such as MiniSSF and ROSS. We expect that with features like good performance, user-friendliness, and portability, the just-in-time parallel simulation will become a common choice for modeling and simulation in the near future.

Model Preemption Based on Dynamic Analysis of Simulation Data to Accelerate Traffic Light Timing Optimisation / Philipp Andelfinger and Sajeev Udayakumar (TUMCREATE Ltd and Nanyang Technological University), David Eckhoff (TUMCREATE Ltd and Technical University of Munich), Wentong Cai (Nanyang Technological University), and Alois Knoll (Technical University of Munich)

Since simulation-based optimisation typically requires large numbers of runs to identify sufficiently good solutions, the costs in terms of time and hardware can be enormous. To avoid unnecessary simulation runs, surrogate models can be applied, which estimate the simulation output under a given parameter combination. Model preemption is a related technique that dynamically analyses the simulation state at runtime to identify runs unlikely to result in a high-quality solution and terminates such runs early. However, existing work on model preemption relies on model-specific termination rules. In this paper, we describe an architecture for simulation-based optimisation using model preemption based on estimations of the simulation output. In a case study, the approach is applied to the optimisation of traffic light timings in a traffic simulation. We show that within a given time and hardware budget, model preemption enables the identification of higher-quality solutions than those found through traditional simulation-based optimisation.

SIMULATION EDUCATION / R15

Simulation Education in Engineering and Computer Science
Antuela Tako (Loughborough University)

Simulation Education in Non-simulation Courses / Roger McHaney (Kansas State University)

In many curricula and degree programs, simulation courses are not required, but these tools and techniques could be beneficial to students preparing for a variety of careers. The current paper describes two examples of simulation education embedded into broader course topics from a development perspective. The examples, from courses generally described in this paper as Cloud Computing and Big Data, offer a recommended approach for exposing students to practical uses of simulation. In the first example, we use simulation techniques to develop a web service emulation response database within a cloud computing environment for software testing. In the second example, simulation techniques provide an approach to generate data sets for learning data analytics techniques.

Games and Simulations in Industrial Engineering Education: A Review of the Cognitive and Affective Learning Outcomes / Mélanie Despeisse (Chalmers University of Technology)

Gamification and experiential learning are increasingly used in education as they create an immersive environment to stimulate students and promote deeper learning. In industrial engineering education, computer simulations and digital games are commonly used to teach technical skills in supply chain management and production planning. Used alongside other teaching methods, they allow students to apply theories learnt and reflect on the impact of their decisions. Other "hands-on" games can also foster the development of professional skills such as leadership, teamwork and communication. Focusing on serious games and game-based learning in industrial engineering, this paper reviews examples to discuss games' benefits and drawbacks as educational tools. Finally, the author suggests ways for game developer to consider how game aspects align with learning outcomes in the cognitive and affective domains.

Perspectives on Teaching Modeling and Simulation in a Department of Computer Science / Armin Kashefi, Faris Alwzinani, and David Bell (Brunel University London)

In this paper, we share our approach to teaching conceptual model development and simulation modeling at a Department of Computer Science in the UK. We explore the challenges and opportunities we face teaching static and dynamic modeling to the 2nd and 3rd year undergraduate students. While our Business Computing students tend not to be as technically savvy as our Computer Science students which at times limits the technical complexity of what we can cover in our courses, we designed the Business Analysis and Process Modeling course as a tool to empower students to analyze and discuss business problems in-depth. The paper reports on the design and findings of the undergraduate teaching of modeling and simulation content. We finalize the paper by providing some concluding remarks and future directions.

SIMULATION OPTIMIZATION / J2

SO in Smart Services
Fermin Mallor (Public University of Navarre)

Delay Guarantee Planning of Call-back Options in Time-varying Service Systems / Galit B. Yom-Tov and Tali Zeitler (Technion - Israel Institute of Technology)

Many service centers offer a "call-back" option, in which customers entering the queue are informed of the anticipated (on-line) wait and can choose to wait either online or off-line till an agent contacts them. We show that such a policy has the potential of both improving service performance and server utilization, by balancing the load between overloaded and underloaded periods. However, our analysis suggests that companies need not offer that service at all times, and that the delay guarantees proposed should be planned according to the anticipated load throughout the day. In order to optimize the operation of such a system, we develop an Iterative Simulation Algorithm to determine what delay guarantees the company should offer in a time-varying environment. Those guarantees depend on service level targets the company wishes to provide and the delay sensitivity of the online vs. off-line customers.

A Comprehensive Electricity Market Model Using Simulation and Optimization Techniques / David Steber, Jakob Hübler, and Marco Pruckner (FAU Erlangen-Nuremberg)

Worldwide Electrical Power Systems (EPSs) are faced with tremendous challenges because of the reduction of greenhouse gas emissions and the increasing number of renewables. EPS analysis can help to show future developments in an uncertain environment and is an important task for the assessment of greenhouse gas emissions. In order to perform such a complex analysis of future EPSs, a huge number of input parameters is needed. Moreover, technical and also economical processes have to be considered. Thereby, one major task is the modeling of electricity markets. In this paper, we present an approach for the modeling of the German EPS including electricity markets using hybrid simulation and mathematical optimization. We contribute an object-oriented electricity market model which can be utilized to study different exchange mechanisms and behavior patterns of generation unit operators. Simulation results show market results for different generation unit operators and realistic market prices.

Analysing the ED Patient Flow Management Problem by using Accumulating Priority Queues and Simulation-based Optimization / Marta Cildoz (Public University of Navarre), Amaia Ibarra (Hospital Compound of Navarre), and Fermin Mallor (Public University of Navarre)

This paper deals with the Emergency Department (ED) patient flow management problem. After triage, where acuity of patient's illness is assessed, each patient waits for treatment. Different care requires disparate resources, leading to different care-paths in the ED. During treatment patients can be in a diversity of treatment stages (waiting for the first consultation, doing clinical tests, waiting for a second consultation, etc.). Therefore, the selection of the next patient to be seen by a physician is not trivial, especially when there are different quality goals to be attained simultaneously. This research investigates disciplines based on accumulation of priority while waiting (APQ). Pure priority disciplines are independent of the quality goals set for the ED while the new ones can be optimized to achieve those goals as much as possible. The optimal APQ policies are obtained by using simulation-based optimization. Both types of policies are tested in a real case.

VENDOR TUTORIALS / R25

MATLAB Simulink / ABS Platform

Agent-based Modeling Approach in MATLAB and Simulink for Autonomous Driving Scenarios / Guang-Lei Wang, Teresa Hubscher-Younger, Wei Li and Fu Zhang (The MathWorks)

Using different new features in MATLAB and Simulink, we will show how to model autonomous driving scenarios with an agent based modeling approach. ABM is a popular simulation approach for autonomous driving scenarios, e.g. in developing driving policies and safety verification. The conventional motion planning and control methods, e.g. PID control, feedback linearization or model predictive control, expect a prediction over the future trajectories of other

traffic participants to avoid collisions. However, actual traffic scenarios involve complicated interactions between drivers (Schwarting, Alonso-Mora and Rus, 2018). To conquer this challenge, the emerging trends are the behavior-aware motion planning and learning-based approaches. ABM could then be exploited to handle the complex environments, while modeling the uncertain interactions with each other. Schwarting, W., Alonso-Mora, J., and D. Rus. 2018. "Planning and Decision-Making for Autonomous Vehicles" In Annual Review of Control, Robotics, and Autonomous Systems. Vol. 1, 2018, pp. 187–210.

Self-Evolving Agent-based Simulation Platform for Predictive Analysis on Socio-Economics by Using Incremental Machine Learning / Dong-oh Kang, Jang Won Bae, Chun-Hee Lee, Joonyoung Jung, and Euihyun Paik (Electronics and Telecommunications Research Institute)

We have developed a self-evolving agent-based simulation platform for predictive analysis of socioeconomic applications. Although continuous model correction is required for reliable prediction whenever new data is added, it is very time-consuming and expensive to repeat the new modeling and calibration tasks of the agent-based socioeconomic simulation applications. We have developed algorithms, software architecture and tools to evolve the agent-based models in an incremental way of data assimilation and automatic model calibration with minimized human intervention via machine learning. We use a changeable component-based structure of agent-based models and the Gaussian optimization technique to derive optimal model configurations from incoming data. Also, we have developed a distributed and parallel simulation engine for large-scale simulation and a web-based GUI tool that manages the simulation and displays results. We will demonstrate the self-evolving process and results of simulation tasks of the Korean housing market and welfare of the elderly with real data.

VENDOR TUTORIALS / R24

Simulation Based Management / Digital Twins

Simulation-based Management (SBM) – Various Examples / Stefan Bengtsson (ÅF)

ÅF packages a major portion of the simulation-related services under the headline SBM. Focus is to convey a more all-embracing view of how simulation competence can and partly should contribute, quite simply by asking the question: "Can we add value in real life, compared to the alternative – not using simulation competence?". Examples from the healthcare sector are used to illustrate, both on macro, meso and micro levels of abstraction. Here models of hospitals-to-be, whole county total care need, and more operational systems will be shown and briefly commented. A combination of Discrete Event and Agent Based modeling is the rule, but based on the philosophy of having a Paradigm-Free approach. Simulation competence should be seen as one of the strongest means to handle change management, decision-making, and general managerial challenges! And it should be considered the by far best way to support system understanding and thinking!

Learnings from 20+ Digital Twins / Lars C. Jacobsen (NIRAS A/S)

Learnings from 20+ Digital Twins. Building a usable Digital Twin is a multidisciplinary task. It requires the combined knowledge of operations research, statistics, supply chain management, domain knowledge, programming, virtual reality, data structures and data structuring, programming, drawing and project management. So is it possible to build a useful Digital Twin with a reasonable effort and what should students learn?

Tuesday 3:30p.m.-5:00p.m.

ADVANCED TUTORIALS / R23

Flexible and Reproducible Simulation Experiments
Susan M. Sanchez (Naval Postgraduate School)

Complex Simulation Experiments Made Easy / Tom Warnke and Adelinde M. Uhrmacher (Universität Rostock)

Diverse methods for complex simulation experiments can contribute to developing and gaining insights into simulation models, for example simulation-based optimization, sensitivity analysis, or statistical model-checking. An effective tool

for conducting simulation experiments must be highly flexible to support such a broad range of experimental methods. Furthermore, to facilitate reproducibility and communication of simulation experiments, an effective tool for simulation experimentation must yield experiment descriptions that are easily portable, executable, and human-readable. In this tutorial we introduce SESSL, a domain-specific language for setting up simulation experiments. SESSL is flexible and extensible, and experiment descriptions are executable, often succinct, and can be executed reproducibly across machines and operating systems. Based on a few examples, we demonstrate how SESSL can be leveraged to easily conduct complex simulation experiments while reusing existing software and methods, and how SESSL's capabilities can be extended and combined with arbitrary simulation software via bindings.

AGENT-BASED SIMULATION / R5

Social and Networking
Vanessa Cedeno (Virginia Tech; Escuela Superior Politécnica del Litoral, ESPOL)

Regression-based Social Influence Networks and the Linearity of Aggregated Belief / Michael J. Garee (Purdue University), Wai Kin Victor Chan (Tsinghua-Berkeley Shenzhen Institute), and Hong Wan (Purdue University)

Consider an agent-based social influence (belief adoption) network where agents share beliefs with neighbors using a linear regression model. One relevant question is: can aggregated, system-level belief also be fit by a linear regression model? Earlier work demonstrated several scenarios where system-level linearity of belief holds. This paper extends that research, varying model and simulation factors through experimental design. When linearity does not hold, we isolate the responsible factors. Finally, we investigate whether system-level linearity is as an absorbing state, that is, when system-level linearity is present at some time t, it continues to hold for all later times.

Social Contagion of Fertility: An Agent-based Simulation Study / Jan Ole Berndt, Stephanie C. Rodermund, and Ingo J. Timm (Trier University)

Social contagion is a process in which the behavior of a social group spreads across a population. We model and analyze this phenomenon with respect to fertility in an agent-based social simulation study. Our model integrates personal motivations for having children and social influences to allow for quantifying their respective impact on fertile behavior. We use a real-world dataset for model calibration and compare three hypothetical scenarios with the reference setting. Our results show that each of the social influences has a statistically significant impact on birth rates in the agent population. Moreover, we identify differences in the effects of social pressure and social support depending on a person's age. This shows that our simulation is not only capable of realistically reflecting family development, but can also provide further insights into the functioning of social mechanisms in a controlled experiment setting.

Collective Problem-Solving in Evolving Networks: An Agent-based Model / Mohsen Jafari Songhori (University of Twente) and Cesar Garcia-Diaz (Universidad de los Andes)

Research works in collective problem-solving usually assume fixed communication structures and explore effects thereof. In contrast, in real settings, individuals may modify their set of connections in the search of information and feasible solutions. This paper illustrates how groups collectively search for solutions in a space under the presence of dynamic structures and individual-level learning. For that, we built an agent-based computational model. In our model, individuals (i) simultaneously conduct search of solutions over a complex space (i.e. a NK landscape), (ii) are initially connected to each other according to a given network configuration, (iii) are endowed with learning capabilities (through a reinforcement learning algorithm), and (iv) update (i.e. create or severe) their links to other agents according to such learning features. Results reveal conditions under which performance differences are obtained, considering variations in the number of agents, space complexity, agents' screening capabilities and reinforcement learning.

ANALYSIS METHODOLOGY / R11

Metamodelling
Wei Xie (Northeastern University)

Metamodel-Assisted Risk Analysis for Stochastic Simulation under Input Uncertainty / Wei Xie and Bo Wang (Northeastern University) and Qiong Zhang (Virginia Commonwealth University)

For complex stochastic systems, simulation can be used to study the system inherent risk behaviors characterized by a sequence of percentiles. In this paper, we develop a Bayesian framework to quantify the overall estimation uncertainty of percentile responses. Suppose that the input parametric families are known. The input model estimation uncertainty is quantified by posterior samples of input parameters. Then, a distributional metamodel is introduced to simultaneously model the percentile response surfaces, which can efficiently propagate the input uncertainty to outputs. Our Bayesian framework can deliver credible intervals for percentiles, and a variance decomposition is further derived to estimate the contributions of input and simulation uncertainties. The empirical studies indicate that our approach has promising performance for system risk analysis.

Unbiased Metamodeling via Likelihood Ratios / Jing Dong (Columbia University), Mingbin Feng (University of Waterloo), and Barry L. Nelson (Northwestern University)

Metamodeling has been a topic of longstanding interest in stochastic simulation because of the usefulness of metamodels for optimization, sensitivity, and real- or near-real-time decision making. Experiment design is the foundation of classical metamodeling: an effective experiment design uncovers the spatial relationships among the design/decision variables and the simulation response; therefore, more design points, providing better coverage of space, is almost always better. However, metamodeling based on likelihood ratios (LRs) turns the design question on its head: each design point provides an unbiased prediction of the response at any other location in space, but perhaps with such inflated variance as to be counterproductive. Thus, the question becomes more which design points to employ for prediction and less where to place them. In this paper we take the first comprehensive look at LR metamodeling, categorizing both the various types of LR metamodels and the contexts in which they might be employed.

Generalized Method of Moments Approach to Hyperparameter Estimation for Gaussian Markov Random Fields / Eunhye Song and Yi Dong (Penn State University)

When a Gaussian Markov random field (GMRF) is used as a metamodel of an unknown response surface for a discrete optimization via simulation (DOvS) problem, the hyperparameters of the GMRF are estimated based on a few initial design points in a large feasible solution space. Although the maximum likelihood estimators (MLEs) are most commonly adopted to estimate these hyperparameters, its computation time increases polynomially in the size of the feasible solution space. We introduce new generalized method of moments (GMM) estimators of the hyperparameters of GMRFs and their initial sampling schemes, and show they are consistent under some conditions. Unlike MLEs, the computation time for these GMM estimators does not depend on the size of the feasible solution space. We show empirically that the GMM estimators have smaller biases and standard errors than MLE for a wide range of initial simulation budget while requiring orders of magnitude smaller computation time.

ANALYSIS METHODOLOGY / CONGRESS HALL

Rare-Event Simulation - II
Dave Goldsman (Georgia Institute of Technology)

Using Regenerative Simulation to Calibrate Exponential Approximations to Risk Measures of Hitting Times to Rarely Visited Sets / Peter W. Glynn (Stanford University), Marvin K. Nakayama (New Jersey Institute of Technology), and Bruno Tuffin (INRIA)

We develop simulation estimators of risk measures associated with the distribution of the hitting time to a rarely visited set of states of a regenerative process. In various settings, the distribution of the hitting time divided by its expectation converges weakly to an exponential as the rare set becomes rarer. This motivates approximating the hitting-time distribution by an exponential whose mean is the expected hitting time. As the mean is unknown, we estimate

it via simulation. We then obtain estimators of a quantile and conditional tail expectation of the hitting time by computing these values for the exponential approximation calibrated with the estimated mean. Similarly, the distribution of the sum of lengths of cycles before the one hitting the rare set is often well-approximated by an exponential, and we analogously exploit this to estimate the two risk measures of the hitting time. Numerical results demonstrate the effectiveness of our estimators.

Sequential Estimation of Steady-State Quantiles: Lessons Learned and Future Directions / Christos Alexopoulos and David Goldsman (Georgia Institute of Technology), Anup C. Mokashi (SAS Institute Inc.), and James R. Wilson (North Carolina State University)

We survey recent developments concerning Sequest and Sequem, two simulation-based sequential procedures for estimating steady-state quantiles. These procedures deliver improved point and confidence-interval (CI) estimators of a selected steady-state quantile, where the CI approximately satisfies user-specified requirements on the CI's coverage probability and its absolute or relative precision. Sequest estimates a nonextreme quantile (i.e., its order is between 0.05 and 0.95) based on the methods of batching and sectioning. Sequem estimates extreme quantiles using a combination of batching, sectioning, and the maximum transformation. Two test problems show both the advantages and the limitations of these procedures. Based on the lessons learned in designing, justifying, implementing, and stress-testing Sequest and Sequem, we discuss future challenges in advancing the theory, algorithmic development, software implementation, performance evaluation, and practical application of improved procedures for steady-state quantile estimation.

Rare-Event Simulation Without Structural Information: A Learning-based Approach / Zhiyuan Huang (University of Michigan), Henry Lam (Columbia University), and Ding Zhao (Carnegie Mellon University)

Importance sampling has been extensively studied as a variance reduction tool in rare-event simulation. The design and efficiency of this method often relies on structural knowledge about the target problem in hand. In this paper, we consider a simple rare-event setting, driven by Gaussian input variates, where there is no direct information about the system of interest, or where the system of interest can only be evaluated through a "black-box" model. This setting mimics, on a basic level, situations where the system of interest could be too complex to analyze as in the conventional importance sampling literature. We investigate an approach based on two-stage sampling, where the first stage learns the rare-event set of interest, and the second stage uses a change of measure that exploits the first-stage finding. We present some guarantees and discuss comparisons of this scheme with more naive approaches.

CASE STUDIES / R4

Logistics & Supply Chains
Michael Machado (FlexSim Brasil, FlexSim)

Simulation Modelling of AGV Transponder Placement / Loo Hay Lee, Ek Peng Chew, Haobin Li, Chenhao Zhou, and Yanchunni Guo (National University of Singapore)

In recent years, automated guided vehicles (AGV) have been widely utilized in automated container terminals for material transfer. AGV can navigate in a facility via communicating with transponders buried beneath the surface of the ground. However, little research has been done on the placement configurations of the transponders which have significance in facility layout, bringing in flexibility and not hindering productivity. In this scope, this study provides a simulation model to evaluate the effectiveness of different transponder placement configurations and helps company decide the best transponder layout.

Adding Urban Hubs in Supply Chains: An Italian Fast Fashion Case Study / Arianna Alfieri and Erica Pastore (Politecnico di Torino)

Nowadays, in the fast fashion industry, high delivery frequencies and small lead times are key factors for market competitiveness. To achieve this goal, many companies are evaluating the possibility of opening urban hubs close to the retailers to guarantee more than one replenishment at the retailers each single day. In this paper, we investigate the impact on the service level, inventory investment and transportation costs of adding such hubs in an Italian fast fashion supply chain.

Brexit: Preparing for the Worst Scenarios / Amr Mahfouz and Declan Allen (Dublin Institute of Technology)

As UK and the EU are in a critical phase of Brexit negotiations, it is important for the transportation and logistics industry to comprehend the full extent of the consequences of Post-Brexit scenarios. In this case, a simulation-based scenario mapping model is developed in collaboration with an Irish food logistics and transportation company to test for the short-term effects of Brexit on company's performance. O'Toole Transport founded in 1996 with one refrigerated vehicle operating from Gal-way. Now, the company has become the first logistics company in Ireland to be awarded the prestigious BRC accreditation for the cross-docking and distribution of chilled and frozen food.

COMPLEX, INTELLIGENT, ADAPTIVE AND AUTONOMOUS SYSTEMS / R22

Industry Applications

Dustin Craggs (The University of Adelaide)

Simulation Framework for Self-Evolving Agent-based Models: A Case Study of Housing Market Model / Jang Won Bae, Euihyun Paik, Dong-oh Kang, Junyoung Jung, and Chun-Hee Lee (Electronics and Telecommunications Research Institute (ETRI))

Agent-based modeling and simulation (ABMS) has been applied to various domain problems. ABM consists of multiple agents and environments and focuses on their interactions. While such characteristics lead to its current popularity, they partially makes hard for the model calibration. Model calibration is generally performed by tuning model parameters, but in the ABM case, its interaction structure should be considered as well due to its huge influences to the results. To resolve this problem, this paper suggests a self-evolving ABMS framework. During the self-evolving process, ABM structure as well as parameters are explored and exploited for the model calibration. In particular, we adopt reconfigurable modeling in the proposed simulation framework, which is derived from Discrete Event System Specification (DEVS) formalism. This paper introduces a housing ABM, and the case study using this model shows that the accuracy of the model prediction was significantly increased through the self-evolving process.

Large-scale Incident-induced Congestion: En-route Diversions of Commercial and Non-commercial Traffic Under Connected and Automated Vehicles / Xiaobing Li and Asad J Khattak (The University of Tennessee, Knoxville)

When large-scale incidents occur on freeways, en-route traffic diversion is one effective strategy to reduce the impact of incident-induced congestion. In corridors with substantial commercial traffic, e.g., trucks, route diversion is complicated compared with non-commercial vehicular traffic, due to tough vehicle maneuvers along alternate routes, and higher safety risk. To address the issue of commercial vehicle diversions to alternate routes in response to large-scale incidents, this paper establishes a microscopic simulation methodology to analyze the impacts of various technologies on en-route diversion under large-scale traffic incidents in real-life corridors for single-unit and multi-unit trucks and passenger vehicles. Results show, in addition to incident duration and lane blockage, important factors as CAV, incident information availability, number of intersections, AADT, impact en-route truck diversions and hence the resulting delays. In future traffic operations practice, customizing incident information to truck and passenger vehicles separately is recommended.

Application of Hysteresis for Stable Segmentation within Digitalized Supply Chain Management / Tim Lauer (Technical University of Dortmund), Martin Schöner (Technical University of Munich), and Frederic Jankowiak and Hans Ehm (Infineon Technologies AG)

Segmentation plays an important role within digitalized supply chain management in the pursuit of competitive advantages, especially in industries where complexity and volatility are present to high degrees. While research in this area is mainly focused on the development of segmentation concepts and the identification of influencing parameters, this paper focuses on the segmentation process and applies a hysteresis to provide stability and autonomous adaptability. Several novel concepts relating to the merger of hysteresis and supply chain segmentation are created, along with a discussion on the process and its requirements. In the end, the theoretical concept is validated by an industrial use case. The results substantiate the concept measured by bound capital and service level.

HEALTHCARE APPLICATIONS / R12

Public health policy evaluation
Jie Song (Peking University)

GEPOC ABM: A Generic Agent-based Population Model for Austria / Martin Bicher (TU Wien) and Christoph Urach and Niki Popper (dwh GmbH)

Since 2015 researchers in Austrian health-care research project DEXHELPP (Decision Support for Health Policy and Planning) benefit from having access to a validated generic agent-based population model (GEPOC ABM) of Austria's population. This simulation model delivers a valid virtual image of Austria's population and is also able to make feasible prognoses. During the last years the model has been extended, remodeled and applied to several use-cases. We were able to add aspects like vaccination strategies, treatment pathways or spread of infectious diseases which underlines the flexibility of the implementation. Yet, a number of challenges have been identified, being the basis to contribute to the general discussion of population models. We will discuss evolving challenges according performance issues and present a newly implemented time-update approach. Thereafter we will discuss different parametrization concepts when adding a disease model. Finally we will present how we integrated GIS information based on Delauney Triangulation.

Mixed Machine Learning and Agend-based Simulation for Respite Care Evaluation / Oussama Batata, Vincent Augusto, and Xiaolan Xie (Mines Saint-Etienne)

Respite care is a new service to decrease burnout risk of caregivers. Hospitalization related to caregivers burnout are costly and should be avoided. Pre-identification of caregivers with severe burnout is crucial to better manage respite care services through smart admission policies and health resources management. In this article we propose a mixed machine learning and agent-based simulation for respite care evaluation taking into account smart admission policies. Results show that neural networks approach demonstrate best results for burnout prediction and allows a significant decrease of undesirable hospitalizations when used as decision aid for admission control.

Simulation Study of Revenue Sharing in Healthcare Alliances / Xiaoquan Gao, Jianpei Wen, and Jie Song (Peking University)

Since the referral system of the Chinese hierarchical healthcare delivery system is still developing, patients can go directly to the specialists for all outpatient care, which results in a significant imbalance of patient flow. To balance the patient flow, the general hospital (GH) and the community healthcare center (CHC) form a healthcare alliance. We propose a two-stage game-theoretic approach to study the operations of the healthcare alliance and employ simulation to analyze the revenue sharing in the alliance. In the first-stage game, two providers negotiate fixed proration rates to share the revenue from referral patients. In the second-stage game, the GH makes the capacity allocation decision and the CHC decides referral rates to maximize their own revenues. We first analyze the Nash equilibrium in the second-stage game through simulation, and then back to the simulation of the first-stage game to investigate the revenue sharing rule's feasibility and efficiency.

HOMELAND SECURITY ENTERPRISE / R17

Infrastructure Threat Analysis
Jalal Mapar (US Dept. of Homeland Security)

Cyber-Physical Simulation and Optimal Mitigation for Shipping Port Operations / Gabriel A. Weaver and Lavanya Marla (University of Illinois at Urbana-Champaign)

Modern shipping ports require computer systems to accommodate an increasing number of port calls, larger vessel sizes, and tighter supply chains. Disruptions to assets on these networks have the potential to propagate to other critical infrastructures at great economic cost. Such disruptions may be introduced intentionally by adversaries that include nation states, organized crime, hacktivists, and insiders. Area Maritime Security Committees (AMSCs) must develop security plans to minimize disruptions' impact. This paper explores one way to couple a simulation of the flow of commodities through a shipping port with an optimization that minimizes the cost of disruptions to the port transportation system. Our intent is to enable stakeholders to run what-if scenarios, to

understand the impact and effect of cyber-physical disruptions, and to optimally mitigate their effect. This research, based on ongoing fieldwork with Port Everglades and the USCG, hopes to improve security policies that integrate cyber and physical effects.

Cyber Risk of Coordinated Attacks in Critical Infrastructures / David Nicol (University of Illinois)

Critical infrastructures such as the electric grid, oil refineries, telecommunications, transportation, water, emergency services, etc., all depend on some cyber infrastructure. Risk analysis of a critical infrastructure to compromised cyber infrastructure is therefore very important, but has certain challenges. This paper examines the problem of integrating analysis of a cyber network with the impacts possible on the critical infrastructures that are possible through cyber access. We find that adding the infrastructure impact cost considerably increases the complexity of the assessment problem.

Investment Portfolio Prioritization for Emerging Homeland Security Threats / Chel Stromgren, Jennifer Hendrickson, and Gabriel Lara (Binera) and Jalal Mapar (DHS)

Government agencies face the challenge of selecting and prioritizing research and development (R&D) investments to address security threats in a dynamic threat landscape. This challenge is compounded by the fact that proposed projects often span technology readiness levels (TRL), cost, and developmental timeframes. The following paper describes a probabilistic, risk-based method that assesses the future expected value of potential investments, incorporating uncertainty from the threat environment - both current and projected - and uncertainty in technology development. The developed method facilitates hedging strategies and redirection of investments at future decision points, based on shifts in threat and reduction of uncertainty; it also captures discounting of achieved value over time to balance projects that have a smaller but faster realization of risk reduction with longer-term solutions that have a large reduction. Ultimately, this approach to R&D investments produces clear, quantitative results for a balanced portfolio that maximizes expected risk reduction.

HYBRID SIMULATION / R6

Panel on Hybrid Simulation
Tillal Eldabi (Brunel University London)

Hybrid Simulation Challenges and Opportunities: A Life-Cycle Approach / Tillal Eldabi (Brunel University), Sally Brailsford (University of Southampton), Anatoli Djanatliev (University of Erlangen-Nuremberg), Martin Kunc (University of Warwick), Navonil Mustafee (University of Exeter), and Andres F. Osorio (Universidad ICESI)

The last 10 years have witnessed a marked upsurge of attention on Hybrid Simulation (HS). The majority of authors define HS as a joint modelling approach which includes two or more simulation approaches (mainly Discrete Event Simulation, System Dynamics and Agent Based Simulation). Whilst some may argue that HS has been in existence for more than 5 decades, the recent rise tended to be more problem driven rather than technical experimentation. Winter Simulation Conference (WSC) 2015, 2016, 2017 have witnessed 3 panels on the purpose, history and definition of HS, respectively. This paper reports on a comprehensive review conducted by the panelists on HS and its applications. The aim of the paper is to move the debate forward by exploring potential platforms for developing concrete avenues for research on HS in conjunction with the modelling life cycle.

INTRODUCTORY TUTORIALS / R31

Success Tips for Simulation Project Excellence
Mohammed Adel Abdelmegid (University of Auckland)

Avoid Failures! Tested Success Tips for Simulation Project Excellence / David Sturrock (Simio LLC)

How can you make your projects successful? How can you successfully create a "Digital Twin"? Modeling can certainly be fun, but it can also be quite challenging. You want your first and every project to be successful, so you can justify continued work. Unfortunately, a simulation project is much more than simply building a model - the skills required for success go well beyond know-

ing a particular simulation tool. A 30-year veteran who has done hundreds of successful projects shares important insights to enable project success. He also shares some cautions and tips to help avoid common traps leading to failure and frustration.

LOGISTICS, SCM, TRANSPORTATION / R21

Simheuristics for Logistics, SCM and Transportation - II
Javier Faulin (Public University of Navarre)

The Team Orienteering Problem with Stochastic Service Times and Driving-range Limitations: A Simheuristic Approach / Lorena Silvana Reyes-Rubiano (Public University of Navarra), Jose M. Mozos and Javier Panadero (Open University of Catalonia), Carlos Ospina-Trujillo and Javier Faulin (Public University of Navarra), and Angel Juan (Open University of Catalonia)

In the context of smart cities, unmanned aerial vehicles (UAVs) offer an alternative way of gathering data and delivering products. On the one hand, in congested urban areas UAVs might represent a faster way of performing some operations than employing road vehicles. On the other hand, they are constrained by driving-range limitations. This paper copes with a version of the well-known Team Orienteering Problem in which a fleet of UAVs has to visit a series of customers. We assume that the rewarding quantity that each UAV receives by visiting a customer is a random variable, and that the service time at each customer depends on the collected reward. The goal is to find the optimal set of customers that must be visited by each UAV without violating the driving-range constraint. A simheuristic algorithm is proposed as a solving approach, which is then validated via a series of computational experiments.

Speeding Up Simulation-based Optimization of Supply Networks by Means of a Multi-population Genetic Algorithm and Reuse of Partial Solutions / Kai Gutenschwager and Bastian Wilhelm (Ostfalia University of Applied Sciences) and Sven Völker (Ulm University of Applied Sciences)

Supply network design is an important strategic operations management problem. The paper discusses the use of simulation-based optimization for solving this task in a performant manner. A three-tier hierarchical approach is presented: On the first tier, a multi-population genetic algorithm decides about the active nodes of the network and assigns product groups to nodes. On the second tier, the production capacities and sourcing paths are determined. On the third tier, a simulation model calculates an objective function value that describes the quality of the network design. While the genetic algorithm acts as a central control instance, the evaluation of the individuals on the second and third tier are parallelized in a computer network. In the course of the optimization process, partial solutions are saved and reused in order to reduce computational cost. The approach is tested on a real-world example of a European supply network.

Simheuristics Applications: Dealing with Uncertainty in Logistics, Transportation, and other Supply Chain Areas / Angel A. Juan (Open University of Catalonia), David Kelton (University of Cincinnati), Christine Currie (University of Southampton), and Javier Faulin (Public University of Navarre)

Optimization problems arising in real-life transportation and logistics need to consider uncertainty conditions (e.g., stochastic travel times, etc.). Simulation is employed in the analysis of complex systems under such non-deterministic environments. However, simulation is not an optimization tool, so it needs to be combined with optimization methods whenever the goal is to: (i) maximize the system performance using limited resources; or (ii) minimize its operations cost while guaranteeing a given quality of service. When the underlying optimization problem is NP-hard, metaheuristics are required to solve large-scale instances in reasonable computing times. Simheuristics extend metaheuristics by adding a simulation layer that allows the optimization component to deal with scenarios under uncertainty. This paper reviews both initial as well as recent applications of simheuristics, mainly in the area of logistics and transportation. The paper also discusses current trends and open research lines in this field.

MANUFACTURING APPLICATIONS / R2

Ecology and Safety Applications
Maheshwaran Gopalakrishnan (Chalmers University of Technology)

Considering Energy in the Simulation of Manufacturing Systems / Tobias Uhlig (Universität der Bundeswehr München), Sigrid Wenzel and Tim Peter (University of Kassel), Johannes Stoldt and Andreas Schlegel (Fraunhofer Institute for Machine Tools and Forming Technology IWU), and János Jósvai (Széchenyi István University)

In recent years, environmental aspects became one of the key interests in manufacturing. Accordingly, simulation studies had to include factors like energy or emissions. This paper aims to provide a comprehensive introduction to the state of the art in modeling of energy and emissions in simulation of manufacturing systems. We review existing literature to develop a landscape of common approaches and best practices. Typical goals and objectives of the reviewed simulation projects are summarized. Furthermore, we will evaluate the structure and life cycle phases of the examined manufacturing systems and look into the requirements and implementation of respective simulation studies. Finally, we will discuss open questions and future trends in this field of research.

Applications for Models of Renewable Energy Sources and Energy Storages in Material Flow Simulation / Johannes Stoldt, Bastian Prell, Andreas Schlegel, and Matthias Putz (Fraunhofer Institute for Machine Tools and Forming Technology IWU)

The increasing reliance on volatile renewable energy sources in the European Union raises questions regarding the future mechanisms of the energy markets. Energy-intensive production industries are particularly expected to take a more active role by shaping their energy demand according to the availability of wind and sun. Hence, they will need to align their production processes with external energy market signals. This paper presents an application example for a Siemens Plant Simulation extension that makes holistic material flow and energy flow studies of factories possible. The so-called eniBRIC class library provides functionalities for investigating the flow of energy between infrastructure and production equipment. Since its latest update, it can also be used to model renewable energy sources as well as energy storages. A case study of the E^3-Research Factory showcases the features of eniBRIC and provides an outlook on future research in the field of energy-flexible production.

Full-scope Simulation of Human-Robot Interaction in Manufacturing Systems / Hans Buxbaum, Markus Kleutges, and Sumona Sen (Niederrhein University of Applied Sciences)

Human-Robot Interaction (HRI) systems were recently introduced in the manufacturing industry. Robots acting autonomously and working in a direct collaboration with humans create a hazard potential, which is influenced by human factors in complex working situations. In this paper, a concept of a full-scope simulator for HRI applications is introduced, followed by a pilot installation of the simulator. Different environmental influences can be created and repeatably reproduced in an experimental environment within the simulator. The HRI full-scope simulator works completely autonomous and enables comprehensible and repeatable ergonomic proband experiments for an optimal design of HRI systems with regard to human factors and allows for statistical conclusions, e.g., about the human situational awareness.

MASM / R14

MASM Keynote: Lars Mönch
John Fowler (Arizona State University)

Reflections on Reference Modeling, Simulation Testbeds, and Reproducibility / Lars Mönch (University of Hagen)

This presentation will discuss requirements for reaching the long-standing goal of designing a reference model for planning and control functions in semiconductor supply chains. A recently proposed simulation testbed for semiconductor supply chains will be described as an intermediate step towards reaching this goal. Some applications of the testbed will be presented. The discussion of the testbed will be related to recent initiatives for replicated computational results and in more general terms to reproducibility of scientific results and open research efforts.

LARS MÖNCH received the master's and Ph.D. degrees in Applied Mathematics from the University of Göttingen, Germany, and the Habilitation degree in Information Systems from the Technical University of Ilmenau. He is a Full Professor with the Department of Mathematics and Computer Science, University of Hagen, Germany. His current research and teaching interests are in production planning and control of semiconductor wafer fabrication facilities, applied optimization and artificial intelligence applications in manufacturing, logistics, and service operations. He has authored over 80 refereed journal papers and book chapters, two monographs, and one edited book. He serves as an Associate Editor for the IEEE Transactions on Semiconductor Manufacturing, the IEEE Transactions on Automation Science and Engineering, the European Journal of Industrial Engineering, Business & Information Systems Engineering, and the Journal of Simulation. He can be reached by email at Lars.Moench@fernuni-hagen.de.

MODELING METHODOLOGY / R26

Panel on Dynamic Data Driven Application Systems
Richard Fujimoto (Georgia Institute of Technology)

Dynamic Data Driven Application Systems: Research Challenges and Opportunities / Richard Fujimoto (Georgia Institute of Technology), Joseph Barjis (Cognizant Technology Solutions), Erik Blasch (Air Force Research Laboratory), Wentong Cai (Nanyang Institute of Technology), Dong Jin (Illinois Institute of Technology), and Seunghan Lee and Young-Jun Son (University of Arizona)

Dynamic Data Driven Applications Systems (DDDAS) is a paradigm where data is dynamically integrated into an executing application, and in reverse, the application dynamically steers the measurement process in a feedback control loop. Since its inception in 2000, the DDDAS concept has been successfully applied to a host of application areas. New technologies are emerging such as big data, the Internet of Things, and cloud/edge computing. With these trends DDDAS is poised to have large-scale impacts in areas such as smart cities, manufacturing, health care, and security, to name a few. Each author describes their views concerning the important research challenges facing the DDDAS paradigm and opportunities for impact in the years ahead.

SIMULATION EDUCATION / R15

Panel: Ethics of Simulation
Andreas Tolk (The MITRE Corporation)

The Ethics of Computer Modeling and Simulation / F. LeRon Shults (University of Agder), Wesley J. Wildman (Boston University), and Virginia Dignum (Delft University of Technology)

This paper describes a framework for ethical analysis of the practice of computer Modeling & Simulation (M&S). Each of the authors presents a computational model as a case study and offers an ethical analysis by applying the philosophical, scientific, and practical components of the framework. Each author also provides a constructive response to the other case studies. The paper concludes with a summary of guidelines for using this ethical framework when preparing, executing, and analyzing M&S activities. Our hope is that this collaborative engagement will encourage others to join a rich and ongoing conversation about the ethics of M&S.

SIMULATION OPTIMIZATION / J2

Metamodel-based Methods in SO
Michael Fu (University of Maryland, Smith School of Business)

Quantile Simulation Optimization with Stochastic Co-kriging Model / Songhao Wang, Szu Hui Ng, and William Benjamin Haskell (National University of Singapore)

Although the mean is a widely-used performance measure for stochastic simulations, the quantiles have become very attractive to measure the variability and the risk of the simulated systems. Optimizing high quantiles, which is typically of interest for decision makers, can be challenging with limited budget as it may cost a large number of simulation runs to obtain estimators for high quantiles with acceptable accuracy. This restricts the application of some traditional Monte Carlo approaches. In this work, we propose a multi-level metamodel (co-

kriging) based algorithm to optimize high quantiles more efficiently. Utilizing non-decreasing properties of quantile functions, we first search on some cheaper and informative lower quantiles, and then search the higher quantiles with a focus on the promising regions identified by lower quantiles. This results in less wastage of budget in non-promising regions. A numerical study is presented to show the power of this algorithm.

Continuous Simulation Optimization with Model Mismatch using Gaussian Process Regression / Alireza Inanlouganji, Giulia Pedrielli, and Georgios Fainekos (Arizona State University) and Sebastian Pokutta (Georgia Institute of Technology)

Multi-fidelity simulation optimization is an emerging area looking at the use of low-fidelity (computationally cheap but inaccurate) models to optimize high-fidelity (expensive and accurate) models. In this context, low-fidelity models exhibit a mismatch to high-fidelity models whose values can be point-wise obtained by querying an expensive simulator. Herein, an efficient multi-fidelity algorithm is proposed for continuous global optimization. The algorithm is made up of an additive model that consolidates low-fidelity and bias (mismatch) predictions. Two sampling criteria with different use of the cumulated high and low-fidelity information are introduced as well as a cheap certificate guiding the decision on whether to sample from the expensive simulator. The performance of proposed algorithms is evaluated using a state of the art stochastic search benchmark algorithm. The results show that the proposed methods can beat the benchmark with improved accuracy, while essentially maintaining the same performance in terms of number of expensive simulations.

Sequential First-Order Response Surface Methodology Augmented with Direct Gradients / Yunchuan Li and Michael Fu (University of Maryland)

We introduce Direct Gradient Augmented Response Surface Methodology (DiGARSM), a new sequential first-order method for optimizing a stochastic function based on Response Surface Methodology (RSM). In this approach, gradients of the objective function with respect to the desired parameters are utilized in addition to response measurements. We establish convergence of the proposed method. We compare methods that use only response information, and those that use only gradient information with the proposed approach, which uses both. Moreover, we conduct numerical simulations to illustrate the effectiveness of the proposed method.

VENDOR TUTORIALS / R25

Automod / FACTS Analyzer

Automod : Material Handling Companies Product of Choice – Come See Why / Daniel Muller (Applied Materials, Inc.)

AutoMod's capability to model large complex automation and material handling systems continues to lead the market. Recent enhancements to AutoMod's material handling systems have increased modeling accuracy and ease-of-use. These advances have made AutoMod one of the most widely used simulation packages. AutoMod's power lies in its performance, scalability and accuracy in detailed modeling of large and complex manufacturing, distribution, automation and logistic operations, leaving the competition behind. Come see why the top material handling companies, high-tech companies, and systems integrators rely on AutoMod to deliver their results!!

Production Systems Analysis and Optimization Using FACTS Analyzer / Amos H.C. Ng and Jacob Bernedixen (Evoma AB)

Factory Conceptual design Tools using Simulation (FACTS) Analyzer is a discrete-event simulation software developed in Sweden with the objective to promote manufacturing decision makers to play the role of simulation analysts, particularly in the conceptual design phase. It features integrated support of simulation-based optimization, specifically using multi-objective optimization algorithms, to facilitate managers/engineers to run optimizations to seek the optimal combinations of design variables to support confident decision making for the design and improvement of production systems. It is also designed with the principle of rapid modeling to aid the users to build models without the need of any programming skills. The concept of rapid modeling and integrated optimization support have facilitated FACTS Analyzer to be a unique and effective tool for production systems analysis and improvement. In this presentation, we will go through six features which make FACTS Analyzer special when compared to other simulation software available in the market.

VENDOR TUTORIALS / R24

Industrial Path Solutions / INCONTROL

Demonstration of Simulation Software Industrial Path Solutions (IPS) / Tobias Forsberg, Peter Mårdberg, Roland Roll, Erik Rilby, and Johan S. Carlson (Fraunhofer Chalmers Centre for Industrial Mathematics)

IPS is a math based software tool for automatic verification of assembly feasibility, design of flexible components, motion planning and optimization of multi-robot stations, and simulation of key surface treatment processes. IPS successfully implements the potential of the virtual world. IPS is developed by Fraunhofer-Chalmers Centre and Fraunhofer ITWM, and distributed by IPS AB and fleXstructures GmbH.

Simulation: Contributing to Insights and Performance Improvement? / Louis Schijve, Fred Jansma, and Frank van Poeteren (INCONTROL Simulation Software)

Information Technology is inextricably linked to virtually all Business processes. And that is exactly where INCONTROL Simulation Software positions its Simulation Software Platform: Enterprise Dynamics. Enterprise Dynamics enables organizations to innovate and improve their business processes e.g. during project preparation & implementation and as an integral part of business operations. At WSC we share our vision, technology insights and business cases on how simulation improved the performance of our clients. INCONTROL Simulation Software is integrated in curricula at Universities, Applied Sciences and R&D Institutes. Together with these partners we implemented solutions in the Process Industry, Transportation, Logistics, Crowd Management and Public Safety.

Wednesday 8:00a.m.-9:30a.m.

ADVANCED TUTORIALS / R23

Inferential Big Data
Adelinde Uhrmacher (University of Rostock)

Data Farming: Better Data, not just Big Data / Susan M. Sanchez (Naval Postgraduate School)

Data mining tools have been around for several decades, but the term "big data" has only recently captured widespread attention. Numerous success stories have been promulgated as organizations have sifted through massive volumes of data to find interesting patterns that are, in turn, transformed into actionable information. Yet a key drawback to the big data paradigm is that it relies on observational data, limiting the types of insights that can be gained. The simulation world is different. A "data farming" metaphor captures the notion of purposeful data generation from simulation models. Large-scale experiments let us grow the simulation output efficiently and effectively. We can use modern statistical and visual analytic methods to explore massive input spaces, uncover interesting features of complex simulation response surfaces, and explicitly identify cause-and-effect relationships. With this new mindset, we can achieve tremendous leaps in the breadth, depth, and timeliness of the insights yielded by simulation.

AGENT-BASED SIMULATION / R5

Agent-based Analysis of Business Applications
Philipp Andelfinger (TUMCREATE Ltd, Nanyang Technological University)

Approach to Improve the Work-Life Balance of Employees Using Agent-based Planning and Simulation-based Evaluation / Thilo Gamber (University of Applied Sciences Ostwestfalen-Lippe) and Gert Zülch (Karlsruhe Institute of Technology)

Working hours that are based on operating requirements may lead to conflicts between working and private times of the employees. In an attempt to reduce or even to avoid conflicts between employees' and operating needs, a hybrid approach is presented here. This approach reduces, or even avoids, conflicts between employees' needs and operational requirements. Starting from a preliminary shift schedule, an improved solution is developed through agent-based time swaps between the employees. The resulting solution is then dynamically evaluated using simulation. The simulation results show the advantages of the improved work schedules by means of personnel-oriented and logistics criteria. With the help of lexicographical preference ordering, an overall solution can be developed that improves the work-life balance of the employees and fulfills operating requirements. Finally, this hybrid approach is demonstrated using the intra-plant logistics department of a process automation devices manufacturer. Furthermore, the effects of diverse swapping heuristics are shown.

An Agent-based Computational Model of the Individual Health Insurance Market / Kevin T. Comer (MITRE Corporation)

This paper focuses on constructing an abstract baseline model of agents, simulating buyers and sellers of health insurance, in the individual health insurance market. Each buyer assesses their expected medical expenses, surveys the insurance contracts available on the market, and decides each year whether to buy insurance, and which plan they will choose. Each seller, upon seeing the costs to provide medical care to its subscriber base, will update the premium price it offers to the market to remain profitable. The aim of this paper is two-fold – to produce a self-sustaining representation of the insurance market that qualitatively represents the health insurance market without any external policy implementations and to quantitatively replicate the large-scale metrics seen in the insurance market, most notably the price elasticity of demand for insurance.

A Generalized Agent Based Framework for Modeling a Blockchain System / Chaitanya Kaligotla and Charles M. Macal (Argonne National Laboratory)

We describe an agent-based conceptual model of a Blockchain system. Blockchain technology enables distributed, encrypted and secure logging of digital transactions in an add-only ledger record. We model and simulate an expanding Blockchain network, describing the participating agents, the transactions, and the verified add-only public ledger record achieving decentralized consensus. All of the essential details of the functioning of the Blockchain including the behaviors and decisions made by agents deciding to join as well as participate

in the market are detailed in the prototype model. The aim of this paper is to illustrate the essential elements and functioning of a Blockchain system, implement a generalized simulation and a measure of Blockchain efficiency from an agent choice and energy cost perspective. Our preliminary results indicate that mining choice (transaction block to verify) coupled with proof of work incentives are critical for energy efficiency.

ANALYSIS METHODOLOGY / CONGRESS HALL

Optimization - I
Peter Frazier (Cornell University)

Achieving Optimal Bias-variance Tradeoff in Online Derivative Estimation / Thibault Duplay, Henry Lam, and Xinyu Zhang (Columbia University)

The finite-difference method has been commonly used in stochastic derivative estimation when an unbiased derivative estimator is unavailable or costly. The efficiency of this method relies on the choice of a perturbation parameter, which needs to be calibrated based on the number of simulation replications. We study the setting where such an a priori planning of simulation runs is difficult, which could arise due to the variability of runtime for complex simulation models or interruptions. We show how a simple recursive weighting scheme on simulation outputs can recover, in an online fashion, the optimal asymptotic bias-variance tradeoff achieved by the conventional scheme where the replication size is known in advance.

Effort Allocation and Statistical Inference for 1-dimensional Multistart Stochastic Gradient Descent / Saul Toscano-Palmerin and Peter Frazier (Cornell University)

Multistart stochastic gradient descent methods are widely used for gradient-based stochastic global optimization. While these methods are effective relative to other approaches for these challenging problems, they seem to waste computational resources: when several starts are run to convergence at the same local optimum, all but one fail to produce useful information; when a start converges to a local optimum worse than an incumbent solution, it also fails to produce useful information. For problems with a one-dimensional input, we propose a rule for allocating computational effort across starts, Most Likely to Succeed (MLS), which allocates more resources to the most promising starts. This allocation rule is based on a novel Gaussian-Process-based statistical model (SGD-GP) for a start's limiting objective value. Unlike previously proposed statistical models, ours agrees with known convergence rates for SGD. Numerical results show our approach outperforms equal allocation of effort across starts and a machine learning method.

On Efficiencies of Stochastic Optimization Procedures under Importance Sampling / Henry Lam (Columbia University), Guangxin Jiang (Shanghai University), and Michael Fu (University of Maryland)

We study and compare the efficiencies of stochastic approximation (SA) and sample average approximation (SAA) for stochastic optimization problems when the decision variables are inside the generating probability distributions or when importance sampling can be applied (as in the case of simulation optimization with Monte Carlo samples). We explain how SA is statistically more efficient than SAA in such contexts, a behavior different from conventional situations where SAA is usually held as the statistically optimal procedure. We support our claim with a theoretical minimax framework and a weak duality argument. We also demonstrate our theoretical findings with some simple simulation examples.

CASE STUDIES / R4

Noble Causes: Healthcare
Stefan Bengtsson (ÅF)

Simulation and Optimization in Complex Emergency Department following the Emergeny Severity Index (esi) and Taking into Consideration Some Decisions Based in Agents to Continuous Improvement / Michael Machado (FlexSim Brasil, FlexSim)

In this case study, we are considering the use of Discrete Event Simulation (DES) and Agent Based Simulation (ABS) with our Flexible Healthcare Simulation Optimization (FHSO) algorithm in Emergency Department (EMD) following the Emergency Severity Index (ESI) with a lot of patient tracks, to optimize staff assignment, and better determinate the number of resources that could

share tasks between the EMD and surgery room taking into consideration the indirect tasks executed by the resources. The main purpose of this study was understand the capacity of the EMD, patient's cycle time or Length of Stay (LOS) and staff assignment for different demands of patients using simulation & optimization inside FlexSim due to its multi method modeling capability (DES and ABS) and high flexibility. The project was handled inside the major Latin America's hospital.

Simulating the Cost-Effectiveness of Strategies to Reduce the Probability of Surgically Transmitted Creutzfeldt-Jakob Disease / Matthew D. Stevenson and Jeremy E. Oakley (The University of Sheffield), Stephen E. Chick (INSEAD), and Lesley Uttley and Christopher J. Carroll (The University of Sheffield)

Creutzfeldt-Jakob disease (CJD) is a fatal disease caused by prions. Prions on surgical instruments are not completely deactivated and subsequent patients may become infected resulting in surgically transmitted CJD (stCJD). Work was undertaken to assess the cost-effectiveness of strategies to reduce the probability of stCJD. Strategies evaluated included: no changes; ensuring that instruments were kept moist; prohibiting instrument migration between sets; and employing single-use instruments. A stochastic mathematical model was constructed with key model parameters populated via elicitation. The model was calibrated to match the possible number of observed stCJD cases between 2005 and 2018, noting that stCJD cases could be misdiagnosed. Results indicated that keeping instruments moist reduced the number of stCJD cases and saved money. Further measures (prohibiting set migration, or single-use instruments) reduced the risk of stCJD cases, compared with keeping instrument moist, but at considerable cost and poor value for money.

Evaluation of Pooling Strategies in the Management of Operating Theatres – a Simulation Based Approach / Shao Wei Sean Lam (SingHealth, NUS); Boon Yew Ang and Eng Hock Marcus Ong (Singapore Health Services, Health Services Research Centre); and Hiang Khoon Tan (Singapore General Hospital, Division of Surgery)

This study reports the development of a discrete event simulation (DES) model improving the operational performance of Operating Theatres (OTs) with respect to the dual outcome measures of OT utilization and the waiting times to surgeries. The model is validated with high fidelity using historical data from 2016-07-01 to 2016-12-31. The model considers 2 emergency OTs and 23 elective OTs spanning across 18 surgical disciplines from a large public hospital in Singapore. The utility of the DES model is demonstrated in the design of a form of the Modified Block Scheduling Strategy, defined as the Open Access policy.

HEALTHCARE APPLICATIONS / R12

Modeling Impact of Interventions using Discrete-event Simulation

Maria Mayorga (North Carolina State University)

Modeling the Impact of Make-Ahead Chemotherapy Drug Policies through Discrete-Event Simulation / Donald Brian Richardson and Amy Ellen Mainville Cohn (University of Michigan)

During an outpatient chemotherapy infusion visit, patients typically have blood work done, see their oncologist in the clinic, wait for the pharmacy to prepare their drugs, and receive their infusion. The time variability at each of these steps can introduce delays, which not only negatively impact the patient but propagate through the system to negatively impact other patients and staff as well. One major opportunity to reduce patient delays is by pre-mixing (i.e. making drugs before the patient arrives for their infusion appointment) at the pharmacy. This, however, requires careful consideration of the trade-off between time savings versus the potential cost of wasting a drug if the patients are deemed ineligible for treatment on the day of their appointment. We present a discrete-event simulation model to predict the effectiveness of various make-ahead drug policies utilizing data from our collaborators at the University of Michigan Rogel Cancer Center (UMRCC).

A Simulation Model to Assess the Impact of Insurance Expansion on Colorectal Cancer Screening at the Population Level / Siddhartha Nambiar and Maria Mayorga (North Carolina State University) and Meghan O'Leary, Kristen Hassmiller Lich, and Stephanie Wheeler (University of North Carolina at Chapel Hill)

Recent health care reform debates have triggered substantial discussion on how best to improve access to insurance. Colorectal cancer (CRC) is an example of a

largely preventable condition, if access to and use of healthcare is increased. Early and ongoing screening and intervention can identify and remove polyps before they become cancerous. We present the development of an individual-based discrete-event simulation model to estimate the impact of insurance expansion scenarios on CRC screening, incidence, mortality, and costs. A national repeated cross-sectional survey was used to estimate which individuals obtained insurance in North Carolina (NC) after the Affordable Care Act (ACA). The potential impact of expanding the state's Medicaid program is tested and compared to no insurance reform and the ACA without Medicaid expansion. The model integrates a census-based synthetic population, national data, claims based statistical models, and a natural history module in which simulated polyps and cancer progress.

HOMELAND SECURITY ENTERPRISE / R17

Modeling and Simulation for Mass Casualty Events

Fredrik Bynander (Swedish Defense University)

Developing a Conceptual Model for Police Custody in the UK / Heather Alexandra Callaghan, Lisa Jackson, Sarah Dunnett, and Antuela Tako (Loughborough University)

The reduction of police officers in UK forces in recent years has reduced the number of staff in police custody, hence it is imperative that staff, and other resources, are utilized appropriately to optimize the custody process. This work aims to develop a simulation model that looks at resource utilisation in police custody. Resource availability can be modelled and tested using discrete event simulation. Developing an accurate conceptual model is a key stage to link the real-world problem and the simulation model. There is minimal literature presenting an accurate police custody conceptual model and hence, that is the focus of this paper. The key sources of information for constructing this model, previous literature, custody record analysis and a custody suite visit are discussed. A final conceptual model is presented with a discussion of how this will be converted into a simulation.

Public Health Management Facing Disaster Response: A Business Process Simulation Perspective / Emilio Sulis and Antonio Di Leva (University of Turin)

This paper focuses on process analysis and computational simulation to address public health management in case of disaster response. By adopting a Business Process Management perspective, we perform organization modeling and analysis as a management tool by comparing results from agent-based and discrete event simulations. We focus on the consequences of a mass tragedy, exploiting real data from an Emergency Department after a crowd disaster where people were stamped as a consequence of mass panic. Our models consider activities with corresponding durations, resources as well as patients arrivals based on real data. Finally, once models were validated by managers, simulations can be used to provide suggestions as well as to propose different set of responses to disaster stress in emergency management.

Agent-based Modeling of a Stadium Evacuation in a Smart City / Margaret Loper, Elizabeth Whitaker, and Michael Riley (Georgia Tech Research Institute) and Scott Duncan, Michael Balchanos, WoongJe Sung, Alexander Markov, Wenxin Zhang, Xiaoshu Fei, and Dimitri Mavris (Georgia Tech)

The concept of Smart Cities is introduced to deal with the problems and challenges that come along with the growth of urbanization. Among all the challenges cities face, one fundamental concern is the safety of its citizens, especially during large sporting events. To test how smart capabilities can affect the evacuation process, an agent-based model was developed of the Georgia Tech football stadium. The model was developed to evaluate possible social behaviors during an evacuation, as well as produce the metrics of interest. To better visualize the results, a user interface was developed that includes a scenario evaluator and a decision making tool.

INTRODUCTORY TUTORIALS / R31

System Dynamics Approach

Chukwudi Nwogu (Brunel University London)

A Primer for System Dynamics Modeling and Simulation / Ignacio J. Martinez-Moyano (Argonne National Laboratory, University of Chicago)

In real-world systems, change and complex interactions are the norm. As a result, stakeholders face challenges and problems when they try to complete tasks and

accomplish important activities in these systems. Linear and traditional analytic approaches fall short in helping us to understand problematic behavior in complex systems and in changing such behavior; they provide faulty and misguided recommendations. The system dynamics approach is based on feedback and control theory, and is well suited for tackling dynamic phenomena. This paper discusses the use and applications of system dynamics modeling, general lessons related to how and when to use this approach, and relevant tools.

INTRODUCTORY TUTORIALS / R6

Tutorial on Conducting Business Process Simulation Studies
Alison Harper (University of Exeter)

A Synthesized Method for Conducting a Business Process Simulation Study / Niels Martin, Benoît Depaire, and An Caris (Hasselt University)

When a company wants to use business process simulation to support decision-making, a simulation study needs to be conducted. Using a clear stepwise method can avoid overlooking key activities during the simulation study and improves the study's credibility towards decision-makers or project sponsors. In this tutorial, a method to perform a simulation study is proposed, which consists of nine steps and uses continuous assessment as a central feedback mechanism. It synthesizes existing methods proposed in literature and positions the actual construction of a simulation model in specialized software in a wider perspective. Given the method's high-level nature, its operationalization is illustrated making use of a real-life simulation study at the emergency department of a hospital, showing that the relative weight of different steps in the method depends upon the project's specificities.

LOGISTICS, SCM, TRANSPORTATION / R22

Applications of Supply Chain and Logistics Using Simulation
Mina Mikhail (German University in Cairo)

Bulk Petroleum Supply Chain Simulation Modeling / Manuel D. Rossetti and Juliana Bright (University of Arkansas)

This paper describes the simulation modeling of bulk petroleum supply chains through an object-oriented simulation library. The paper focuses on the conceptual modeling that is useful for resource and transportation capacity analysis during contingency and war gaming analysis. In addition, the modeling provides the capability to understand how surges in demand will affect inventory service. The methods, insights, and capabilities developed within this research facilitate the analysis of bulk petroleum military supply chains and also permit the analysis of the resilience of commercial bulk petroleum supply chains under conditions of disruption.

A Supply Chain Model of Hip Stem Prostheses Produced Using 3D Printing: A Comprehensive Description of the Simulation Model / Margaret M. Golz, Richard Wysk, Russell King, Colin Nolan-Cherry, and Stephen Bryant (North Carolina State University)

Medical device companies have a growing interest in additive manufacturing (AM) for orthopedic implant production. AM provides an opportunity for economically feasible customized implants to supplement the current traditionally-manufactured, standard-sized prosthesis. In this paper, a simulation model is developed to analyze the supply chain of custom hip stem production using AM. A test case is implemented into the simulation model to determine the supply chain's responses in key performance indices, such as production lead time of a uniquely customized prosthesis and resource utilization, to resource level variations based on current state of the practice for additive and subtractive manufacturing. The method of this research was to use a simulation focused on measuring the performance of the supply chain for hip stem implants in order to determine supply chain resource requirements.

Comparison of Approaches to Encrypt Data for Supply Chain Simulation Applications in Cloud Environments / Kai Gutenschwager (Ostfalia University of Applied Sciences); Markus Rabe (TU Dortmund); and Marcel Theile and Bastian Wilhelm (Ostfalia University of Applied Sciences)

A main characteristic in the field of supply chain simulation is that typically several independent organizations are involved. However, most simulation studies only consider a very limited number of different organizations. One main reason is that suppliers usually do not want to publish sensitive data, such as

resource capacities or cost rates to their customer. In this paper we present an overall architecture to tackle this problem of multi-organizational simulation studies storing all relevant data at an independent third party, which also carries out all experiments and distributes the results as a cloud service. In order to define scenarios, different rights to use the provided data can be granted to other participants. The necessary user-specific encryption of datasets needs to be established on the underlying data base structure. In this paper we focus on three approaches for storing and encrypting data along with a detailed comparison in terms of performance.

LOGISTICS, SCM, TRANSPORTATION / R21

Simulating Forecasts in Transportation Systems
Bahar Biller (SAS Institute, Research and Development)

Dynamic Model of the Passenger Flow on Rail Baltica / Juri Tolujew, Irina Yatskiv, and Ilya Jackson (Transport and Telecommunication Institute) and Tobias Reggelin (Otto von Guericke University Magdeburg)

This paper describes the design and application of a model simulating the passenger flows on the high-speed rail line Rail Baltica. The proposed model allows one to define passenger flow service indicators, according to data on the behavior of potential passengers that take the train in different localities along Rail Baltica. If corresponding baseline data is provided and the duration of the longest trip will not exceed one day, the model can be used to study processes on other railways with a similar structure. The developed model simulates movements and accumulation of passengers at stations and in trains on four sections connecting five cities along Rail Baltica. Besides that, the model allows for studying particular scenarios related to large sports or other events that will take place near one or several cities through which the railway passes.

Simulating the Impact of External Demand and Capacity Constraints in Aerospace Supply Chains / David James Grainger Allen, Adrian Murphy, and Joseph Martin Butterfield (Queen's University Belfast); John Stephen Drummond and Stephen James Robb (Bombardier Aerospace Belfast); and Peter Laurence Higgins and John Paul Barden (Northern Ireland Technology Centre)

By outsourcing major aircraft systems to Tier 1 suppliers, original equipment manufacturers depend heavily on their supply chain to meet the growing demand for aircrafts. However, capacity constraints upstream of the Tier 1 suppliers increase the risk of schedule disruption. Discrete event simulation is commonly applied to analyze capacity constraints in manufacturing systems while analytical models assess financial investment scenarios for capital equipment. This paper demonstrates a combined simulation and analytical modeling approach to simulate the operational and financial implications of capacity constraints in aerospace supply chains. A three-tier supply chain is modeled with the option of investing to remove a capacity constraint in a sub-tier supplier. The results demonstrate how a supplier's capacity investment decisions and the increasing demand for aircrafts can affect their cash flow and delivery schedule adherence.

Strategic Supply Chain Design for an Austrian Winter Road Service Provider / Thomas Felberbauer (St. Pölten University of Applied Sciences), Alexander Hübl and Klaus Altendorfer (University of Applied Sciences Upper Austria), and Josef Gattringer (State Government Upper Austria)

Snowplow operations are critical for public safety and economic success in countries where difficult driving conditions occur in winter. Specifically, the salt supply ensuring good driving conditions is a crucial factor. In this paper, the strategic supply chain design of a winter service provider in Austria is investigated. Two research directions on the influence of bigger and fewer salt silos per depot and the logistic costs for a unique summer salt purchasing strategy are addressed applying two independent solution approaches. On the same data basis, a simulation model is developed and a mixed integer linear problem is applied to answer the respective research questions. The first study shows that the current depot availability is quite good but that bigger and fewer salt silos per depot could be a risk. Finally, the second study shows the logistic costs for the unique summer salt purchasing strategy and the optimal salt-warehouse locations.

MANUFACTURING APPLICATIONS / R2

Simulation in Operations
Jens Weber (Heinz Nixdorf Institute)

Ford's Power Train Operations: Changing the Simulation Environment 2 / Michael Higgins (Ford Motor Company) and John Ladbrook (Ford Motor Company, University of East London)

At the 2001 Winter Simulation Conference, the progress of simulation in Ford Motor Company's PowerTrain Manufacturing Engineering (PTME) department was documented in a paper that focused on the contributions of the department in changing the simulation environment at Ford. This paper reviews the progress, changes, and issues in the intervening years experienced by the UK-based PTME simulation team. It summarizes the development of a toolset from a model building capability to data analysis, to experimentation, and results analysis. It outlines how capabilities have expanded while maintaining quick delivery of results; it references the managements' changing attitude and how academic research has advanced simulation in PTME.

Real-time Simulation in Manufacturing Systems: Challenges and Research Directions / Giovanni Lugaresi and Andrea Matta (Politecnico di Milano)

In the last years, the increase of data availability together with enhanced resource flexibility shed light on the possibility to develop planning and control methods with real-time inputs. Literature is rich of approaches to simulate, to quickly evaluate system performances, and to take decisions based on optimization criteria. Further, simulation has been identified as one of the pillars for the Industry 4.0 revolution. However, the lack of a generally recognized approach and methodology to deal with real-time decision-making through simulation is evident. Simulation approaches can and should play a central role in industry for the years to come. This position paper analyses the current research context with a brief state of the art on existing approaches, includes considerations about the issues for implementing Real-Time Simulation (RTS) concepts and their current state of development. Finally, it outlines research directions for the simulation community.

Real-time Batching in Job Shops Based on Simulation and Reinforcement Learning / Tao Zhang, Shufang Xie, and Oliver Rose (Universität der Bundeswehr München)

Real-time batching in job shops decides 1) whether to start processing a batch or to wait for more jobs joining the batch, and 2) which batch should be processed first. It is addressed as a sequential decision-making problem and formalized based on Markov decision processes. By adding a dummy batch, which means no batches are selected and all batches wait for additional jobs, the first decision-making is generalized to the second. A simulation-based neural fitted Q learning is introduced to solve the Markov decision processes and build a decision maker. The well-trained decision maker decides which batch in a batch list should be processed first at each decision epoch. The experiment results show that the proposed approach outperforms some other decision rules.

MASM / R14

Quality Applications
Claude Yugma (Ecole des Mines de Saint-Etienne)

Virtual Metrology Modeling Based on Gaussian Bayesian Network / Wei-Ting Yang (École des Mines de Saint-Étienne (CMP)), Jakey Blue and Agnès Roussy (Ecole des Mines de Saint-Etienne (CMP)), Marco Reis (University of Coimbra), and Jacques Pinaton (STMicroelectronics Rousset)

For the past decades, Virtual Metrology (VM) has been widely studied and covered in the literature for semiconductor industries where cycle time is a critical aspect and the elimination of non-productive metrology measurements is expected to significantly contribute to its reduction. A wide variety of approaches has been proposed but not effectively implemented. An ideal VM model should be able to provide accurate predictions and to reveal the hidden relationship among production/process factors. For this aim, we employ the Gaussian Bayesian Network (GBN) to investigate the implicit relationship not only between the metrology and the control factors but also among the production/process parameters. Instead of working purely as a black-box data-driven methodology, GBN enables the flexibility to integrate domain

knowledge through the corresponding connected graph. The effectiveness of proposed approach is validated using real industrial data from a Chemical-Mechanical Polishing (CMP) process.

The Detection and The Control of Machine/Chamber Mismatching in Semiconductor Manufacturing / Aabir Chouichi (Ecole des Mines de Saint-Etienne,CMP Georges Charpak; STMicroelectronics Crolles); Jakey Blue and Claude Yugma (Ecole des Mines de Saint-Etienne,CMP Georges Charpak); and Francois Pasqualini (STMicroeletronics Crolles)

Achieving desired yields in advanced manufacturing industries, as is the case for semiconductor fabrication, requires perfectly matching the performance of parallel machines/chambers at all production steps. Moreover, in the high-mix/low-volume manufacturing environment of the IC makers, the need for highly precise production processes makes the task of matching identical machines/chambers more and more complicated and challenging. In this paper, a methodical approach to deal with machine/chamber mismatching using all available data such as sensor data, product measurements, and maintenance log is proposed and validated with real practices. In fact, after detecting and identifying the key variables source of variance in the process, a modeling step known as Virtual Metrology is performed to quantify accurately the recipe adjustments i.e., R2R control, which will match as much as possible both sensor data and metrology measurements between similar machines/chambers.

A Bayesian Indicator for Run-to-Run Performance Assessment using Industrial Risk / Taki Eddine Korabi (STMicroelectronics, LIS lab. / Aix Marseille Université); Guillaume Graton (Ecole Centrale Marseille); El Mostafa El Adel and Mustapha Ouladsine (Aix-Marseille Universite); and Jacques Pinaton (STMicroelectronics)

This paper proposes a performance indicator based on the Bayesian theory. This indicator is used for assessing the behaviour of Run-to-Run controllers. The indicator is calculated by analyzing four main points: the output/target error, the output dispersion, the out of tolerance (oot) rate and the industrial risk. The proposed Bayesian method has been tested on the Run-to-Run loops of a semiconductor manufacturing foundry.

MASM / R15

Supply Chain Modeling - II
Stephane Dauzère-Pérès (Ecole des Mines de Saint-Etienne)

Aggregated Hierarchical Modelling and Simulation in Semiconductor Supply Chains / Georg Laipple (Robert Bosch GmbH), Oliver Schönherr (Saxony Media Solutions GmbH), Marcin Mosinski (Robert Bosch GmbH), Elias Winter (Saxony Media Solutions GmbH), and Kai Furmans (University Karlsruhe (KIT))

The semiconductor sector is undergoing one of the fastest market growths. Demand is increasing and market forecasts are optimistic. New markets are emerging and product portfolios are broadening significantly. Dynamic supply chains are developing with increasing number of customers, products, suppliers and manufacturing partnerships. Up to now due to modeling complexity and computation time constraints, disjoint systems are used for local supply chain control and optimization. For efficient control, these complex semiconductor supply chains require a global approach for simulation and optimization. This is the motivation for this conceptual paper. In the conceptual part this paper introduces and discusses novel model aggregation approaches and model validity improvements with novel hierarchical modeling concepts. In the modeling part this paper incorporates that into an aggregated simulation model approach as well as a novel hierarchical interface concept for coupling of disaggregated analytical and simulation models to systematically improve overall model validity at Bosch.

Generic Data Model for Semiconductor Manufacturing Supply Chains / Georg Laipple (Robert Bosch GmbH), Stéphane Dauzère-Pérès (Mines Saint-Etienne), Thomas Ponsignon (Infineon Technologies AG), and Philippe Vialletelle (STMicroelectronics)

Semiconductor manufacturing systems, with several hundreds of different production steps, reentrant loops, cleanroom conditions and a job shop organization, are probably the most complex production systems and so is the manufacturing data structure. This high complexity requires precise planning, modelling and simulation to improve manufacturing transparencies and avoid planning inefficiencies. Although many modelling approaches for semiconductor production systems have been published, much less work has been conducted to define a

common data model that supports the industrial complexity. This paper presents a common conceptual data model for semiconductor supply networks, developed in close collaboration by three European semiconductor manufacturers. Described semiconductor manufacturing use cases motivate the proposed conceptual data model. This model includes master entities, defining the structure of semiconductor supply networks with common definitions of key elements, and tracing entities, describing time dependent changes and events of the system. Expected benefits of the conceptual data model are also discussed.

Collaboration in Supply Chains for Development of CPS Enabled by Semantic Web Technologies / Hartwig Baumgaertel (University of Applied Sciences Ulm); Hans Ehm, Sabrine Laaouane, and Jan Gerhardt (Infineon Technologies AG); and Anna Kasprzik (University of Hannover)

The development of Industrial Cyber-Physical Systems (ICPS) requires new ways of collaboration between ICPS vendors and companies which provide them with parts and components. As ICPS extend existing systems, e.g. machines or healthcare equipment, by electronic components, new supply chains will evolve between companies which were not connected before. Hence, traditional methods for collaboration will not fit for them anymore. We propose a new approach for collaborations in ICPS development. It relies on technologies from the Semantic Web and consists of a web platform where ICPS vendors and vendors of electrical, electronical, information and communication technology components can virtually meet. Component vendors can describe their products, ICPS element vendors their product ideas and requirements. To match requirements and offers, semantic descriptions of both are necessary. Then, matching of requirements and offers will be realized by semantic reasoners. They have to find RDF graph chains which link requirement and offer descriptions.

SIMULATION OPTIMIZATION / R24

New Approaches in SO - I
Helena Ramalhinho (Universitat Pompeu Fabra)

A Stochastic-Kriging-based Multiobjective Simulation Optimization Algorithm / Sebastian Rojas-Gonzalez (KU Leuven); Hamed Jalali (NEOMA Business School); and Inneke Van Nieuwenhuyse (Hasselt University, KU Leuven)

We consider the multiobjective simulation optimization problem, where we seek to find the non-dominated set of designs evaluated using noisy simulation evaluations, in the context of numerically expensive simulators. We propose a metamodel-based scalarization approach built upon the famous ParEGO algorithm. Our approach mainly differentiates from ParEGO and similar algorithms in that we use stochastic kriging, which explicitly characterizes both the extrinsic uncertainty of the unknown response surface, and the intrinsic uncertainty inherent in a stochastic simulation. We additionally integrate the Multiobjective Optimal Computing Budget Allocation ranking and selection procedure in view of maximizing the probability of selecting systems with the true best expected performance. We evaluate the performance of the algorithm using standard benchmark test functions for multiobjective optimizers, perturbed by heterogeneous noise. The experimental results show that the proposed method outperforms its deterministic counterpart based on well-known quality indicators and the fraction of the true Pareto set found.

A Sort-based Interest Matching Algorithm With Two Exclusive Judging Conditions For Region Overlap / Tianlin Li, Wenjie Tang, Yiping Yao, and Feng Zhu (National University of Defense Technology)

As the IEEE standard for distributed simulation, High-Level Architecture (HLA) defines the data distribution management (DDM) service to filter unnecessary communication among federates. In DDM, interest matching algorithm is essential for the message filtering. Among existing interest matching algorithms, sort-based algorithms have been proven to be the most efficient method in most scenarios. However, existing sort-based algorithms still have some drawbacks, the overhead of sorting the bounds can be further reduced and a portion of unnecessary bit or matching operations can be eliminated. In this paper, we propose a binary search enhanced sort-based interest matching algorithm (BSSIM). Based on two exclusive judging conditions for region overlap, sorting overhead can be remarkably reduced. Moreover, unnecessary bit or matching operations can be eliminated by binary searches. Experimental results show that BSSIM algorithm outperforms existing sort-based algorithms, and considerable performance improvement can be achieved.

SIMULATION OPTIMIZATION / J2

SO for Large Problems
Christine Currie (University of Southampton)

Multi-fidelity Simulation Optimisation for Airline Disruption Management / Luke Rhodes-Leader (Lancaster University), Bhakti Stephan Onggo (Trinity College Dublin), David John Worthington (Lancaster University), and Barry L. Nelson (Northwestern University)

The airline industry faces many causes of disruption. To minimise financial and reputational impact, the airline must adapt its schedules. Due to the complexity of the environment, simulation is a natural modelling approach. However, the large solution space, time constraints and system constraints make the search for revised schedules difficult. This paper presents a method for the aircraft recovery problem that uses multi-fidelity modelling including a trust region simulation optimisation algorithm to mitigate the computational costs of using high-fidelity simulations with its benefits for providing good estimates of the true performance.

Practical Considerations in Selecting the Best Set of Simulated Systems / Thomas Monks and Christine S.M. Currie (University of Southampton)

In many practical problems, simulation models are used to support complex decision-making processes comparing hundreds or thousands of solutions. These problems typically have a key objective but the final decision may be dependent on other factors, which cannot be incorporated into the simulation model. In such cases, decision-makers may request a short list of 'good' solutions, which work well for the main objective and satisfy one or more chance constraints. While fully sequential ranking and selection procedures can be effective at solving these problems, surveys of experimentation practice suggest that they are under-utilized, potentially due to difficulties automating commercial software. We develop an approach with just two stages of replications. The approach, which has been designed to cope with the use of common random numbers, draws on ideas from indifference zones and makes use of bootstrapping to find a subset of high quality solutions. A Python implementation is freely available.

A New Framework for Parallel Ranking and Selection Using an Adaptive Standard / Linda Pei and Barry L. Nelson (Northwestern University) and Susan R. Hunter (Purdue University)

When we have sufficient computational resources to treat a simulation optimization problem as a ranking & selection (R&S) problem, then it can be "solved." R&S is exhaustive search---all feasible solutions are simulated---with meaningful statistical error control. High-performance parallel computing promises to extend the R&S limit to even larger problems, but parallelizing R&S procedures in a way that maintains statistical validity while achieving substantial speed-up is difficult. In this paper we introduce an entirely new framework for R&S called Parallel Adaptive Survivor Selection (PASS) that is specifically engineered to exploit parallel computing environments for solving simulation optimization problems with a very large number of feasible solutions.

Wednesday 10:00a.m.-11:30a.m.

ADVANCED TUTORIALS / R23

Global Health Simulation
Susan M. Sanchez (Naval Postgraduate School)

Modeling Diseases: Prevention, Cure and Management / Christine SM Currie and Thomas Monks (University of Southampton)

Diseases, like death and taxes, seem an inevitable part of life, with much of modern medicine acting to prevent, cure or manage them effectively. Modeling of diseases began over a century ago and has been one of the success stories of applied mathematics and, more recently, computer simulation. In this article, we describe modeling of both communicable and non-communicable diseases, and provide a review of the relevant literature. Two case studies are discussed, the first describing a modeling study of tuberculosis and HIV and the second capacity planning for stroke services. Our aim is to instigate a discussion of how modeling should be used in the future to answer the most up-to-date questions about global health, particularly those of disease prevention.

AGENT-BASED SIMULATION / R5

Public Health & Elderly Care
Sarah Wise (University College London)

Parameterization and Calibration of Micro-Simulation Model for Cervical Cancer and HIV in Zambia / Kasey River Jones, Joey Morris, Georgiy Bobashev, and Sujha Subramanian (RTI International)

Zambia has one of the highest rates of cervical cancer in the world. To help policy makers make future intervention decisions regarding cervical cancer, we created a micro-simulation model to simulate cervical cancer and HIV in Zambia. Model calibration faced two major challenges: (1) Much of the available input data was on women in the United States, which do not allow calibration to align to the age-specific targets from Zambia; (2) Significant computational resources were not always available. We addressed issue one by creating age-specific calibration parameters to help better match specific targets. Issue two was addressed by using predictive models before conducting calibration simulations to discard parameter sets that are likely to produce poor results. This paper will demonstrate these two modeling strategies and show the dramatic effect they had on our ability to accurately calibrate to model targets.

Agent-based Modeling and Simulation of Individual Elderly Care Decision-Making / Daniel S. Lebherz, Fabian Lorig, and Ingo J. Timm (Trier University)

Recent statistics predict an increasing demand for care services in elderly care as a result of demographic change. To forecast the amount, location, and type of emerging care demand, existing approaches like Microsimulation must be revised. These approaches lack consideration of the fact that every decision for a specific type of care is dependent on the individual care recipient's situation and personal preferences. To close this gap, it seems reasonable to extend existing Microsimulation approaches by means of Agent-based Social Simulation. The goal of this work is the development of an agent-based model, that enables the simulation of individual decision-making processes. The presented model is based on sociodemographic data to take systemic properties and individual situations into account. Additionally, sociological actor types are used to implement individual preferences and the characteristics of care recipients. To evaluate the proposed approach, a case study using German census data is presented.

Evaluation of Lifestyle Effects on Chronic Disease Management / Elham Shojaei, Emilio Luque, Dolores Rexachs, Alvaro Wong, and Ferancisco Epelde (Universitat Autonoma de Barcelona)

In this study, we propose a model that helps to analyze the behavior of chronic disease patients with a focus on heart failure patients based on their lifestyle. We consider how living conditions affect signs and symptoms of chronic disease and, accordingly, how these signs and symptoms affect chronic disease stability. We use an agent-based model, a state machine, and a fuzzy logic system to develop the model. Specifically, we model the required "living condition" parameters that can influence required medical variables. These variables determine the stability class of chronic disease. The model allows creation of virtual patients with a given pathology and analysis of their impact on quality of the Emergency Department. Analysis of the Emergency Department's quality based on modeling and simulation enables us to develop new planning strategies for efficient care systems.

ANALYSIS METHODOLOGY / CONGRESS HALL

Optimization - II
Jeff Hong (Fudan University)

Optimal Allocation for Sample Average Approximation / Prateek Jaiswal, Harsha Honnappa, and Raghu Pasupathy (Purdue University)

We consider a single stage stochastic program without recourse with a strictly convex loss function. We assume a compact decision space and grid it with a finite set of points. In addition, we assume that the decision maker can generate samples of the stochastic variable independently at each grid point and form a sample average approximation (SAA) of the stochastic program. Our objective in this paper is to characterize an asymptotically optimal linear sample allocation rule, given a fixed sampling budget, which maximizes the decay rate of probability of making false decision.

A Simulation-based Prediction Framework for Stochastic System Dynamic Risk Management / Wei Xie (Northeastern University, Academic); Pu Zhang (Rensselaer Polytechnic Institute); and Ilya O. Ryzhov (University of Maryland)

We propose a simulation-based prediction framework which can quantify the prediction uncertainty of system future response and further guide operational decisions for complex stochastic systems. Specifically, by exploring the underlying generative process of real-world data streams, we first develop a nonparametric input model which can capture the important properties, including non-stationarity, skewness, component-wise and time dependence. It can improve the prediction accuracy, and the posterior predictive distribution can quantify the prediction uncertainty accounting for both input and stochastic uncertainties. Then, we propose the simulation-based prediction framework which can efficiently search for the optimal operational decisions hedging against the prediction uncertainty and minimizing the expected cost occurring in the planning horizon. The empirical study demonstrates that our approach has promising performance.

Fully Sequential Ranking and Selection Procedures with PAC Guarantee / Ying Zhong and Jeff Hong (City University of Hong Kong)

In the ranking-and-selection field, many current existing fully sequential procedures are developed under the indifference-zone (IZ) formulation which assumes an optimality gap between the best alternative and the others. In this paper, by modifying one classical fully sequential procedure, Paulson's procedure, we devise a new type of fully sequential procedure which can provide the probably approximately correct (PAC) selection guarantee. The procedure is able to select an alternative within a certain distance from the best one with the desired probability even when the IZ assumption is violated. In order to provide this selection guarantee, we lose some efficiency on the procedure. However, we show, both theoretically and numerically, that this efficiency loss is limited and acceptable when the number of alternatives is large.

CASE STUDIES / R4

In-house Logistics
Sven Spieckermann (SimPlan AG)

Consulting In-house Supplying Routes in the Automotive Industry / Marcelus Fabri (Universitat Pompeu Fabra, SEAT S.A.) and Helena Ramalhinho (Universitat Pompeu Fabra)

This case study presents a consulting work applied in a car-assembling company, SEAT S.A. The focus was on the Logistics field, precisely, the in-house supplying routes, which are the most important logistic flow to supply the workstations' demands. We carried out a methodology compound by the Simulated Iterated-Local-Search to compute the best set of routes to deliver the demands from the company's warehouse towards the workstations. Concerning the results, it is possible to state that the methodology developed by this work outperformed the current results found in the car-assembling company, regarding the items supplied, the number of waiting materials and the distance traveled. Furthermore, we highlight that our methodology can deal with both small boxes and big containers classes of SKU.

Key Performance Indicators and Analysis Method for Ship Block Logistics Flow in Shipyards / Huiqiang Shen, Yong-Kuk Jeong, and Jong Gye Shin (Seoul National University); Philippe Lee (Xinnos Co., Ltd.); and Jong Hun Woo, Yong Gil Lee, Sang Hun Kim, and Ju Hyeon Jeong (Korea Maritime and Ocean University)

Most of large shipyards in Korea, Japan and China, ships are constructed by dividing them into blocks. Fabricated blocks are stocked throughout shipyard in accordance with the process statuses. Due to the physical constraints of the blocks, special transportation equipment such as transporter is utilized to move the blocks, during which, efficient transportation plan and verification process is necessary because of the limited number of transporters. However, most shipyards are struggling to efficient transportation planning as well as performance analysis due to various reasons. In order to efficiently establish and analyze transportation logistics plan, a method to define and analyze the key performance indicators is proposed in this research.

Simulation of a Coal Lading Port / Ilka Habenicht (SimPlan AG)

This case study considers the simulation of a coal lading port in order to determine which extensions are needed based on expected capacity demands. These investigations are executed in cooperation with the German company TAKRAF GmbH which planned and constructed the considered port. Processes at this port are influenced by uncertainties, like the provided coal mix from mines and transportation times from mines to the port or meteorological disturbances. The maximum capacity of the current state of the port was determined at a first step. Components which mainly limit the maximum outcome were identified. Based on these results, different extension scenarios were evaluated.

JOINT SESSION: HYBRID SIMULATION & LOGISTICS, SCM, TRANSPORTATION / R22

Mobility
Abdullah Alabdulkarim (Majmaah University)

Modelling and Analysis of Intermodal Passenger Operations in a Cruise Terminal / Jaume Figueras Jove and Antoni Guasch Petit (Universitat Politècnica de Catalunya) and Josep Casanovas-García (Barcelona Supercomputing Center)

In this paper we present a discrete event simulation model of a cruise terminal for decision support and strategic planning. The main objective is to provide an analysis tool for systems with high capacity constraints, heterogeneous subsystems, time-dependent demand and stochastic passenger transfer and travel times. Cruise terminals are connected by bus to a transport interchange or intermobility center where passengers are transferred to taxis. All terminals are affected by capacity constraints such as the number of bus platforms for passenger pick-up and drop-off and the limited queuing capacity for taxis and passengers. Passenger arrivals are time-dependent and cruise-type-dependent. The purpose of this model is to support the strategic decision-making process through what-if-scenarios. Decisions involve determining the required number of bus platforms, taxi buffer sizes and passenger distribution policies, among other factors. The results identified and proposed the solution of bottlenecks and enabled a sensitivity analysis to be performed.

Rebalancing and Fleet Sizing of Mobility-on-Demand Networks with Combined Simulation, Optimization and Queueing Network Analysis / Peter Bazan and Anatoli Djanatliev (Friedrich-Alexander University Erlangen-Nürnberg); Christoph Lauer (AUDI AG, Development Autonomous Driving); and Marco Pruckner and Reinhard German (Friedrich-Alexander University Erlangen-Nürnberg)

Car rental companies have to operate the fleet of vehicles considering a cost effective fleet sizing and rebalancing of the vehicles. Additionally, they have to ensure a good vehicle availability at the rental stations. We present a simulation model combined with optimization and queueing network analysis for mobility-on-demand networks with one-way car sharing. The system is modeled as a closed queueing network. On the one hand, this allows an estimation of the vehicle availability; on the other hand, constraints for the optimization model can be derived from the mathematical equations of the queuing network model. To optimize the total revenue, the optimization model considers price incentives for customer trips and cost of empty trips resulting in a mixed-integer linear programming problem. The simulation uses the optimization component for an optimized operation of the mobility-on-demand networks and computes the optimal fleet size, the cost of empty runs, and the vehicle availability.

Simulating Different Levels of Car Class Upgrades in a Car Rental Company's Operations / Abdullah A. Alabdulkarim (Majmaah University)

The car rental business has experienced recent growth under a fiercely competitive market. This paper describes a generic discrete event simulation tool for studying the complex nature of a car rental company's operations. To construct the tool, we conducted several interviews with experts to first establish the proper requirements, after which we collected relevant data for populating the simulation model, thereby determining the best strategies for car class pricing and upgrade offers that would result in the highest revenue. A realistic case study was conducted to assess the tool and gain a better understanding of the underlying system. Finally, simulation experiments regarding rental prices and car upgrades were designed, and the system was run, achieving a 0.5% error for various performance criteria. For the given case, we found that two upgrade offers and setting prices slightly higher than the average customer budget provides the best strategy.

INTRODUCTORY TUTORIALS / R31

Business Models with System Dynamics
Christoph Kogler (University of Natural Resources and Life Sciences, Vienna)

Fast and Effective Living Business Models with System Dynamics: A Tutorial on Business Cases / Kim Warren (Strategy Dynamics Ltd)

This tutorial is for analysts, consultants, and teachers of business modeling. No prior experience is needed. Simulating business challenges and plans has until recently been difficult and time-consuming, but things have changed! We will take you through an "agile" process that makes quantified, working simulations practical for non-experts to build, quickly and reliably. And, we need these tools! Spreadsheet-based methods just cannot handle the interdependencies, feedback, thresholds, and intangible factors that pervade all but the simplest cases. The resulting Living Business Models display with total transparency the factors that management recognizes, and the causality driving the performance outcomes they are interested in. Since everyone sees the same rigorous picture, they get a "joined-up" view that fully explains how everything has been changing. This allows them to explore likely future outcomes under alternative assumptions, decisions, and strategies.

INTRODUCTORY TUTORIALS / R6

Tutorial on Statecharts Modelling & Simulation
Daniel Gaspar (FEUP)

Introduction to Statecharts Modeling, Simulation, Testing, and Deployment / Simon Van Mierlo and Hans Vangheluwe (University of Antwerp - Flanders Make vzw)

Statecharts, introduced by David Harel in 1987, is a formalism used to specify the behaviour of timed, autonomous, and reactive systems using a discrete-event abstraction. It extends Timed Finite State Automata with depth, orthogonality, broadcast communication, and history. Its visual representation is based on higraphs, which combine graphs and Venn diagrams. Many tools offer visual editing, simulation, and code synthesis support for the Statechart formalism. Examples include STATEMATE, Rhapsody, Yakindu, and Stateflow, each implementing different variants of Harel's original semantics. This tutorial introduces modeling, simulation, and testing with Statecharts. As a running example, the behaviour of a traffic light, a simple timed, autonomous, and reactive system is modeled. We start from the basic concepts of states and transitions and explain the more advanced concepts of Statecharts by extending the example incrementally. We discuss several semantic variants, such as STATEMATE and Rhapsody. We use Yakindu to model the example system.

LOGISTICS, SCM, TRANSPORTATION / R21

Operations Planning under Input Model Uncertainty
Alp Akcay (Carnegie Mellon University)

Risk Assessment in Pharmaceutical Supply Chains under Unknown Input-Model Parameters / Alp Akcay and Tugce Martagan (Eindhoven University of Technology) and Canan G. Corlu (Boston University)

We consider a pharmaceutical supply chain where the manufacturer sources a customized product with unique attributes from a set of unreliable suppliers. We model the likelihood of a supplier to successfully deliver the product via Bayesian logistic regression and use simulation to obtain the posterior distribution of the unknown parameters of this model. We study the role of so-called input-model uncertainty in estimating the likelihood of the supply failure, which is the probability that none of the suppliers in a given supplier portfolio can successfully deliver the product. We investigate how the input-model uncertainty changes with respect to the characteristics of the historical data on the past realizations of the supplier performances and the product attributes.

Propagation of Input Uncertainty in Manufacturing Process Flow Simulations / Bahar Biller and Anup C. Mokashi (SAS Institute, Research and Development)

We consider a discrete-event stochastic simulation that represents a generic manufacturing process flow and assume the availability of limited knowledge about part inter-arrival times and machine processing times. We investigate how the state-of-the-art simulation methodologies can be utilized to propagate input

inter-arrival-time and service-time uncertainty through such a manufacturing simulation. We quantify the impact of limited knowledge on steady-state manufacturing-line performance measures such as utilization, lead time, inventory, and throughput. First, we conduct experiments for single-stage manufacturing systems where we additionally study the impact of yield loss uncertainty on annual throughput predictions. Then, we switch our focus to multi-stage manufacturing systems and investigate whether there may be situations in which it becomes difficult to correctly identify the system bottleneck. We conclude with the identification of the manufacturing system stages that contribute most to the variability in lead time and inventory predictions.

Probability Distribution of the Length of the Shortest Tour Between a Few Random Points: A Simulation Study / Alexander Vinel and Daniel Silva (Auburn University)

Inspired by an application in the field of on-demand public transportation, we perform a Monte Carlo simulation study on the probability distribution of the length of Traveling-Salesman-Problem (TSP) tours between small numbers of random locations. We consider a fixed convex region, where we generate a fixed number of random locations from a known probability distribution and find the corresponding euclidean TSP tour for them. We simulate this process extensively and perform both quantitative and qualitative analyses of the resulting experimental distribution for the TSP tour length. We show that, under certain assumptions on the shape of the region and the probability distribution of locations, the length of the TSP tour is well-approximated by a normal distribution, even for as few as five locations. Furthermore, we propose experimental models for estimating the mean and standard deviation of the tour length.

MANUFACTURING APPLICATIONS / R2

Simulation, Optimization, Analytics
Christoph Laroque (University of Applied Sciences Zwickau)

A Simheuristic Algorithm for Solving an Integrated Resource Allocation and Scheduling Problem / Ludovica Maccarrone (Sapienza, ACTOR s.r.l.); Daniele Ferone (Universitat Oberta de Catalunya); Tommaso Giovannelli (Sapienza); and Javier Panadero and Angel A. Juan (Universitat Oberta de Catalunya)

Modern companies have to face challenging configuration issues in their manufacturing chains. One of these challenges is related to the integrated allocation and scheduling of resources such as machines, workers, energy, etc. These integrated optimization problems are difficult to solve, but they can be even more challenging when real-life uncertainty is considered. In this paper, we study an integrated allocation and scheduling optimization problem with stochastic processing times. A simheuristic algorithm is proposed in order to effectively solve this integrated and stochastic problem. Our approach relies on the hybridization of simulation with a metaheuristic to deal with the stochastic version of the allocation-scheduling problem. A series of numerical experiments contribute to illustrate the efficiency of our methodology as well as their potential applications in real-life enterprise settings.

Introducing Simulation and Optimization in the Lean Continuous Improvement Standards in an Automotive Company / Ainhoa Goienetxea Uriarte (University of Skövde), Tommy Sellgren (Volvo Car Corporation), Amos H.C. Ng (University of Skövde), and Matías Urenda Moris (University of Uppsala)

The highly competitive automobile market requires automotive companies to become efficient by continuously improving their production systems. This paper presents a case study where simulation-based optimization (SBO) was employed as a step within a Value Stream Mapping event. The aim of the study was to promote the use of SBO to strengthen the continuous improvement work of the company. The paper presents all the key steps performed in the study, including the challenges faced and a reflection on how to introduce SBO as a powerful tool within the lean continuous improvement standards.

Production Log Data Analysis for Reject Rate Prediction and Workload Estimation / Andras Pfeiffer, Dávid Gyulai, and Ádám Szaller (MTA SZTAKI) and László Monostori (MTA SZTAKI, Budapest University of Technology and Economics)

The main focus of the research presented in this paper is to propose new methods for filtering and cleaning large-scale production log data by applying statistical learning models. Successful application of the methods in consideration of a production optimization and a simulation-based prediction framework for decision

support is presented through an industrial case study. Key parameters analysed in the computational experiments are fluctuating reject rates that make capacity estimations on a shift basis difficult to cope with. The most relevant features of simulation-based workload estimation are extracted from products' final test log, which process has the greatest impact on the variance of workload parameters.

MASM / R14

Capacity and Assignment Applications
Anna Rotondo (Dublin City University)

Capacity Planning Challenges in a Global Production Network with an Example from the Semiconductor Industry / Sarah Biwer and Michael Filipek (Infineon Technologies AG, WU Vienna University of Economics and Business) and Emel Arikan and Werner Jammernegg (WU Vienna University of Economics and Business)

In the global, volatile semiconductor market classical capacity planning approaches need to be improved to stay competitive. Resource bottlenecks constrain production, limit the availability of finished product which can be promised to the customer and cause different utilization levels. Bottlenecks may vary periodically due to changes in supply and demand. One bottleneck can have an impact on a whole global production network. How can bottlenecks be identified and allocated in the capacity plan of global enterprises with alternative production routes and daily updated, integrated planning across sites? This paper reviews how capacity planning is covered in the literature, focusing on the semiconductor industry. Local vs. global capacity planning in global networks is identified as an area where there is limited research available so far. A case study of a semiconductor company is used to show the relevance of that area and what solutions have been found by practitioners so far.

Operator Resource Modelling in a Multiple Wafer Sizes Fabrication Environment Using Discrete Event Simulation / Georg Seidel (Infineon Technologies Austria AG); Andre Naumann and Patrick Preuss (D-SIMLAB Technologies GmbH); and Soo Leen Low, Boon Ping Gan, and Chew Wye Chan (D-SIMLAB Technologies Pte Ltd)

Infineon Villach wafer fab facility has a unique characteristic of producing products of different wafer sizes with shared resources, both operators and tools. Daily adaptation of resource allocation to manage changing workloads is done dynamically and imposes challenges in providing high accuracy simulation forecast. In this paper, we discuss the modelling approach that we have taken to represent this dynamic feature, where resources are adjusted in simulation based on WIP situation. The concept is similar to acquiring KANBAN prior to running a production lot. KANBAN quantity is kept at a minimum number in low WIP situation, while the quantity is kept at maximum number at high WIP situation. These values were adjusted by studying the historical moves observed for a period of 3 months. Using this approach, we managed to improve the forecast quality by 7 percentage points in moves and 64 percentage points in WIP.

Generalization of EF-based Assignment Strategies for Cycle Time Optimization at Complex Wet Stations / Anna Rotondo (Irish Manufacturing Research) and John Geraghty and Paul Young (Dublin City University)

When solution approaches are developed to facilitate decision processes in real manufacturing systems, fundamental information constraints may apply. The data required by theoretically efficient decision support tools may not be available or accessible; as a consequence, the possibility of implementing the solutions developed is compromised. In this paper, assignment strategies subjected to information constraints and previously developed for a particular wet station are generalized to wet stations characterized by different tool configurations and production recipes. These strategies have been designed to be integrated with data management systems and make use of real time data to minimize the stations' average cycle time. The experiments run aim at supporting the hypothesis that progressive incorporation of details on the system status in assignment strategies enhances the strategies' performance. The relevance of data-driven simulation-based decision support is demonstrated with reference to wet stations operating in a real semiconductor manufacturing facility.

MASM / R15

Scheduling, Capacity Planning and Simulation-Optimization
Cathal Heavey (University of Limerick)

A Review of Simulation-Optimization Methods with Applications to Semiconductor Operational Problems / Amir Ghasemi (University of Limerick), Georg Laipple (Robert Bosch GmbH), and Cathal Heavey (University of Limerick)

Recent advances in simulation optimization (SO) research and explosive growth in computing power have made it possible to optimize complex manufacturing system problems. Semiconductor manufacturing is known as one of the most complex manufacturing systems. Based on a review of literature in the field of semiconductor manufacturing operational and planning problems, there is little reference to SO methods, an approach that has many advantages over other solution approaches. In this paper, we first distinguish between different users of SO then consider different approaches of SO applied to semiconductor and other manufacturing problems. The article then describes the main operational and planning issues in semiconductor manufacturing drawing actively from a Bosch fab, which could be addressed using SO. Finally, we attempt to provide insights on how SO can be applied to these problems.

A CP Model for a Scheduling Problem with Limited Secondary Resources Compared to a DES Model / Dirk Doleschal and Karlheinz Bock (Technische Universität Dresden)

An efficient scheduling of bottleneck areas within the semiconductor manufactory gets more and more important. Due to the high complexity within the manufacturing area it is currently not possible to optimize the whole (or even a bigger part of the) factory at once. So mostly only work center specific optimization approaches are investigated. Typically scheduling problems only deal with two dimensions – jobs and equipment. But in some areas of semiconductor manufactory also a third dimension have to be considered – a limited secondary resource. In this paper a Constraint Programming model for such limited secondary resource problems is presented. Thereby the scheduling model also deals with setup matrices for the first and also secondary resource. The modeling of this CP model is shown in detail and the results are compared to a discrete event simulation. The test data for the first tests are orientated on real production data.

Implementing a New Genetic Algorithm to Solve the Capacity Allocation Problem in Photolithography Area / Amir Ghasemi (University of Limerick), Kamil Erkan Kabak (Izmir University of Economics), and Cathal Heavey (University of Limerick)

Photolithography plays a key role in semiconductor manufacturing systems. In this paper, we address the capacity allocation problem in the photolithography area (CAPPA) subject to machine dedication and tool capability constraints. After proposing the mathematical model of the considered problem, we present a new genetic algorithm named RGA which was derived from a psychological concept called Reference Group in society. Finally, to evaluate the efficiency of the algorithm, we solve a real case study problem from a semiconductor manufacturing company in Ireland and compare the results with one of the genetic algorithms proposed in the literature. Results show the effectiveness and efficiency of RGA to solve CAPPA in a reasonable time.

SIMULATION OPTIMIZATION / J2

New Approaches in SO-II
Andrea Matta (Shanghai Jiao Tong University)

A Scalable Approach to Enhancing Stochastic Kriging with Gradients / Haojun Huo and Xiaowei Zhang (HKUST) and Zeyu Zheng (University of California, Berkeley)

It is known that incorporating gradient information can significantly enhance the prediction accuracy of stochastic kriging. However, such an enhancement cannot be scaled trivially to high-dimensional design space, since one needs to invert a large covariance matrix that captures the spatial correlations between the responses and the gradient estimates at the design points. Not only is the inversion computationally inefficient, but also numerically unstable since the covariance matrix is often ill-conditioned. We address the scalability issue via a novel approach without resorting to matrix approximations. By virtue of the so-called Markovian covariance functions, the associated covariance matrix can be invertible analytically, thereby improving both the efficiency and stability

dramatically. Numerical experiments demonstrate that the proposed approach can handle large-scale problems where prior methods fail completely.

Simulation-based Benders Cuts: A New Cutting Approach to Approximately Solve Simulation-Optimization Problems / Mengyi Zhang and Andrea Matta (Politecnico di Milano), Arianna Alfieri (Politecnico di Torino), and Giulia Pedrielli (Arizona State University)

Large solution space is one of the main features of simulation-optimization problems. Reducing the cardinality of the set of alternatives is a key point for increasing the efficiency of simulation-optimization methods. In this work, a new cutting approach is proposed for this purpose. The approach exploits the Benders Decomposition framework that can be effectively applied when the simulation-optimization problems are represented using Discrete Event Optimization models. Benders Decomposition subproblems represent the simulation components, hence, cuts can be easily generated observing the values of the variables while a system alternative is simulated, without solving any sub-problem. The cut generation procedure is proposed to approximately solve the Server Allocation Problem in a tandem queueing system. Results on randomly generated instances show its effectiveness in decreasing the computational effort by reducing the solution space.

Multi-fidelity Models for Decomposed Simulation Optimization Problems / Nicla Frigerio (Politecnico di Milano), Ziwei Lin (Shanghai Jiao Tong University), and Andrea Matta (Politecnico di Milano)

Hierarchical problem decomposition methods are widely used in optimization when the scale of the problem is large. The master problem is hierarchically decomposed to several sub-problems and the detail level of the sub-problems increases during the optimization from bottom to top. When simulation is used to estimate unknown functions, models with different detail are used at each level. However, the simulation outputs used to solve the sub-problems of a hierarchy level are not used anymore at higher levels. An approach is proposed in this paper to reuse these experiment data to improve the efficiency of the simulation-optimization algorithm. A multi-fidelity surrogate model is built in each sub-problem to guide the search of the optimum. The performance of the approach is numerically assessed with the goal of understanding its potentialities and the effect of algorithm parameters over optimization results.

WORLD CAFÉ / R17

World Café Harvest
Margaret Loper (Georgia Tech Research Institute)

This session harvests the results of World Café discussions held during Monday and Tuesday lunch times at the conference. Ideas, questions, and concerns around the topics are captured during the World Café - I and II discussions in previous two days. During this session, the discussion topics and the diverse individual perspectives will be briefed out from a shared perspective.

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Orem, UT 84097
www.flexsim.com
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Fraunhofer-Chalmers Centre
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Chalmers Science Park, SE-412 88
Gothenburg, Sweden
http://www.fcc.chalmers.se/
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IPS is a math based software tool for automatic verification of assembly feasibility, design of flexible components, motion planning and optimization of multi-robot stations, and simulation of key surface treatment processes. IPS successfully implements the potential of the virtual world. IPS is developed by Fraunhofer-Chalmers Centre and Fraunhofer ITWM, and distributed by IPS AB and fleXstructures GmbH.

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3528 BJ
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www.incontrolsim.com
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3 Apple Hill Drive
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https://www.mathworks.com/
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MOSIMTEC
Booth #13
297 Herndon Parkway, Suite 301
Herndon, VA 22182
http://mosimtec.com/
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NIRAS
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2830 Virum
Denmark
https://www.niras.dk/
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Rockwell Automation (Arena® Simulation Software)
Booth #7
9500 Arboretum Blvd, Suite 400
Austin, TX 78759
www.rockwellautomation.com
Arena® Discrete Event Simulation Software, from Rockwell Automation, is designed for use throughout an enterprise, supporting both in-depth analyses of a particular functional area (e.g., manufacturing, logistics, customer service, healthcare and more) and analysis of processes that span several functional areas. Arena offers the unparalleled ease-of-use, flexibility, scalability, and domain experience required for modeling any aspect of a business enterprise. Based upon the concepts of the SIMAN simulation language and the Visual Designer animation package, Arena uses a flowchart-style modeling methodology that does not require you to program in another environment like C++ or Java. Its hierarchical modeling and an extensive graphical library help make Arena the world's leading simulation system. Rockwell Automation Inc. (ROK) is a global leader in industrial automation and smart manufacturing, with a keen focus on technology innovation, domain expertise, and integrity and corporate responsibility which fuels our success.

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www.sagepublishing.com
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SAS
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SAS Campus Dr.
Cary, NC 27513
www.sas.com
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Siemens
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Muenchen, Germany 81730
www.siemens.com/plm
Siemens PLM Software, a business unit of the Siemens Digital Factory Division, is a leading global provider of software solutions to drive the digital transformation of industry, creating new opportunities for manufacturers to realize innovation. With headquarters in Plano, Texas, and over 140,000 customers worldwide, Siemens PLM Software works with companies of all sizes to transform the way ideas come to life, the way products are realized, and the way products and assets in operation are used and understood. For more information on Siemens PLM Software products and services, visit www.siemens.com/plm.

Simio Simulation & Scheduling Software
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Sewickley, PA 15143
www.simio.com
Simio Simulation and Scheduling Software is the most advanced solution on the market. With simulation, it is the only software that is fully object oriented with process and objects being defined graphically with no programming. Unlike other scheduling software, Simio allows you to introduce risk into your production schedule with its patented Risk Based Planning and Scheduling. This dual function in Simio not only helps you improve your business performance from a facility design perspective, but also helps you maximize business results by optimizing the use of critical resources and assessing the risk associated with operational decisions.

SimPlan AG
Booth #3
Sophie-Scholl-Platz 6
Hanau, Germany 63452
www.simplan.de/en/
SimPlan AG – Simulation Solutions for Production and Logistics Processes
SimPlan AG was established in 1992 as a service provider for the simulation of company processes. Today, the company has 117 employees and is the leading full-service simulation specialist in Germany. We support customers with our extensive know-how, many years of experience and modern methods in the analysis and optimization of their company processes.

SIMUL8 Corporation
Booth #32
225 Franklin Street, 26th Floor
Boston, MA 02110
www.simul8.com
Since 1994 SIMUL8 Corporation has been producing powerful, intuitive simulation software. From strategic to operational, our simulation software can handle as much complexity as you need it to, meaning you get the results you need to make decisions fast. SIMUL8's powerful solutions have already helped global industry leaders transform their organizations and achieve higher levels of performance. From single user licenses to application development frameworks, we have the simulation product to fit your needs.

The Society for Modeling & Simulation International (SCS)
Booth #4
11315 Rancho Bernardo Road, Suite 139
San Diego, CA 92127
www.scs.org
SCS is the world's premier professional society devoted to modeling and simulation (M&S). Through our quality journals, JDMS and SIMULATION, and our international conferences, we serve M&S professionals from around the world. Our membership includes individuals from industry, government, and academia whose interests span all aspects of M&S.

Systems Navigator
Booths # 33 & 34
Delftechpark 38
Delft, The Netherlands 2628XH
www.systemsnavigator.com
Systems Navigator is an independent software consultancy company. Since 2003, our employees are working around the globe for a wide range of customers on the most challenging projects. We assist our customers in making better decisions on where to spend their capital by demonstrating the impact of change through simulation modelling that can calculate a wide range of future scenarios. Our Dropboard platform for planning & scheduling helps companies optimize their operations, improve customer service and maximize the use of their assets. Systems Navigator is a distributor of Arena and Simio simulation software and is the creator of Scenario Navigator.

Talumis
Booth #5
Dolderseweg 2H
3712 BP
Huis ter Heide, The Netherlands
http://talumis.com
Talumis - Optimization through Simulation. The expertise of TALUMIS is focused on optimizing logistics in industrial environments and especially in the area of production, warehousing, material handling and (bulk) supply chains. Talumis has developed a special module for the FlexSim simulation environment, called FloWorks. FloWorks is a powerful additional module for the FlexSim simulation software used to accurately analyze and optimize the logistics of bulk, fluids or gas flows in large networks. FloWorks is a radical new approach to combine discrete events and continuous processes. FlexSim - FloWorks is used in supply chain modeling, chemical plants, food production or any other industry involving logistics of bulk, fluids or gas flows.

Virtual Manufacturing
Booth #21
Fabriksgatan 21
SE 412
Gothenburg, Sweden
https://www.virtual.se/
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Visual Components
Booth #2
Vänrikinkuja 2
FI-02600 Espoo, Finland
https://www.visualcomponents.com/
Visual Components is a leading developer of 3D manufacturing simulation software and solutions. Founded in 1999 by a team of simulation experts, we started with a humble goal – to make manufacturing design and simulation technology easy to use and accessible to manufacturing organizations of all sizes. Today, Visual Components is recognized as a global leader in the manufacturing simulation industry and trusted technology partner to many leading brands. We offer machine builders, system integrators, and manufacturers a simple, quick, and cost-effective solution to design and simulate production lines. With solutions for manufacturing design, sales, and application development, Visual Components software is trusted by hundreds of organizations worldwide to support critical planning and decision-making processes. Visual Components is headquartered in Helsinki, Finland and has subsidiaries in Lake Orion, Michigan and Munich, Germany, along with a global partner network of partners and resellers.

VMS Global
Booth #6
1952 Gallows Road, Suite 110
Vienna, VA 22182
http://vms-solutions.com/
VMS Global, Inc. has provided simulation-based planning and scheduling solutions for high-tech industries including semi-conductor, LCD/OLED panel manufacturing. As a leading SCM solution provider, VMS Global continuously improves the applications with current issues of world-renowned customers like Samsung Electronics, Samsung Display, LG Display, SK Hynix, Micron Technology. VMS Global makes the best efforts to grow with our customers through continuous technology development, and grows to be the technology-oriented venture company fulfilling CSR (corporate social responsibility)

Xcelgo
Booth #29
Rugaardsvej 5
Ry, Denmark 8680
https://xcelgo.com/
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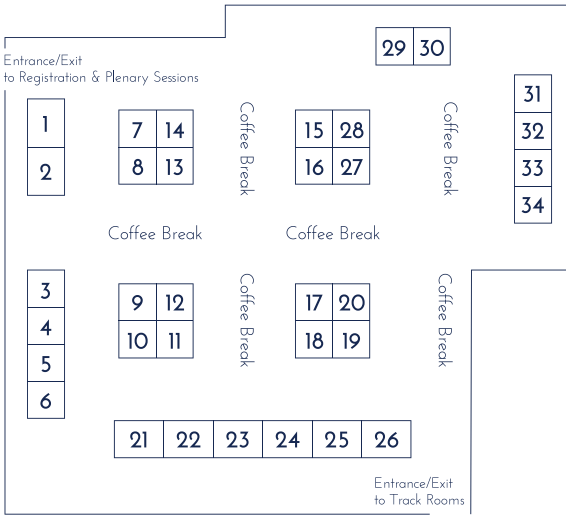

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Winter Simulation WSC'19 Conference

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Conference Theme: *Simulation for Risk Management*

WSC 2019 focus is on the use of simulation to address a wide range of individual and societal risks.

From its very beginnings over 70 years ago, simulation has been a powerful tool for assessing potential risks and guiding us in making decisions under uncertainty. The 2019 conference seeks to highlight the latest simulation technologies for more accurately anticipating risks and for making more robust decisions in the face of uncertainty, ambiguity, and variability. These include methods for robust and accurate simulation modeling, analysis, and optimization. We also invite papers describing applications of simulation to risk management in a broad variety of domains, including healthcare, disaster response, power grids, construction, transportation, finance, cybersecurity, and more.

WSC 2019 KEYNOTE SPEAKER
Dr. Robert Atlas
Director, National Oceanic and Atmospheric Administration (NOAA) Atlantic Meteorological Laboratory

Title: Modeling and Simulation for Reducing the Risks Associated with Extreme Weather
The reduction of losses related to hurricanes and other extreme weather phenomena involves many complex aspects ranging from purely theoretical, observational, computational and numerical, to operational and decisional. A correct warning can lead to proper evacuation and damage mitigation, and produce immense benefits. However, over-warning can lead to substantial unnecessary costs, a reduction of confidence in warnings, and a lack of appropriate response. In this chain of information, the role played by scientific research is crucial. The National Oceanic and Atmospheric Administration (NOAA), in combination with the National Aeronautics and Space Administration (NASA), other agencies, and universities is contributing to these efforts through observational and theoretical research to better understand the processes associated with extreme weather. This includes model and data assimilation development, Observing System Experiments (OSE), and Observing System Simulation Experiments (OSSE) designed to ascertain the value of existing observing systems and the potential of new observing systems to improve weather prediction and theoretical understanding. We describe innovative research for developing advanced next-generation global and regional models to improve weather prediction, and the application of OSSEs to optimize the observing system.

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WSC 2019 features a comprehensive program ranging from introductory tutorials to state-of-the-art research and practice. Planned tracks are:

- Advanced Tutorials
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All submissions will be **peer reviewed**. Accepted **papers** will be published in the digital version of the conference proceedings stored in IEEE and ACM repositories. All papers must be presented for the paper to be fully published, copyrighted and disseminated. Instructions, information, submission forms and procedures are available on the WSC website. **Extended abstracts** will appear in the INFORMS Simulation Society archives, but not in the ACM and IEEE digital proceedings.

Each accepted paper must have a separate, paid registration. Only under highly unusual circumstances, and at the discretion of the conference leadership, will an author be allowed to present more than one paper on a single registration. Authors wishing to do so must contact the Program Chair by September 1, clearly describing which papers the authors wish to present under the single registration, and why an exception to the conference policy is warranted. Unless permission is granted, an author planning to present two papers will be required to pay for two registrations.

Contributed Paper Deadlines

- **April 5, 2019**: Electronically submit contributed papers not previously published or presented. Each submission must use the Word or LaTeX templates on the Authors Kit. The page size in the proceedings is 8.5 by 11 inches (21.6 cm by 27.9 cm). Papers should be at most 12 pages (including an abstract of not more than 150 words), except for introductory tutorials, advanced tutorials, and panel sessions, for which the limit is 15 pages. Submission implies that an author will attend WSC 2019 and present the paper, and all clearance required for publication of the paper will be obtained by June 29 2019. Submissions must be made through the WSC website.
- **May 31, 2019**: Notification of acceptance
- **June 29, 2019**: Authors electronically submit corrected papers to the Proceedings Editor.
- **July-Aug. 2019:** The Proceedings Editors contact authors with formatting-related queries and corrections, with individual deadlines for submitting the camera-ready copy.

Poster Session or Ph.D. Colloquium (One or the other, submission to both Poster Session and the PhD Colloquium is not allowed for 2019)

- **August 2, 2019**: electronically submit 2-page extended abstracts for presentations in the Poster Session and Ph.D. Student Colloquium.
- **August 28, 2019**: Notification of acceptance to authors (including details about submitting slides, and formats of the posters).
- **September 7, 2019**: Final extended abstracts due.
- **October 25, 2019**: Slides for the presentation due (see guidelines in the track information)
- **December 8, 2019**: Bring your poster to WSC 2019. The Poster Madness Session and Ph.D. Colloquium both run on Sunday December 8, so participation in both is not possible.

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CD-ROM and USB Key Instructions

Getting Started

The contents of this product are designed to be viewed directly from the media (CD or USB Key) using a web browser. To access content, double click the main HTML file named **2018 WSC Content.htm** and it will open in your web browser.]

Software Requirements

Windows®: Windows 2000 (Service Pack 2) or newer, Internet Explorer (version 7 or newer recommended) with Active Content enabled, or Netscape, Mozilla, Firefox, Opera, or any browser able to use Java and JavaScript (the AOL browser is not supported by this product), Java 1.4 or newer (if using a web browser other than Internet Explorer), The free WebEx Player for recorded presentations.

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Adobe Reader 7.0 or later for viewing PDF content, the free Adobe Flash Player for multimedia content, Additional software may be needed to view some materials included on this product.

Additional software may be needed to view some materials included on this product.

Need Help?

Refer to the "Software Requirements.htm" file located on this disc for general product support, downloading and installing Adobe Reader, and copying this product to your hard disk or network. A complete help file is accessible from the main menu of this product (internet connection optional). Omnipress technical phone support is available at 608-246-2600 (Mon-Fri 8am-5pm CST) or by e-mail at digital@omnipress.com. Limited support for UNIX and Linux systems. This product is not supported if hosted on a web server.

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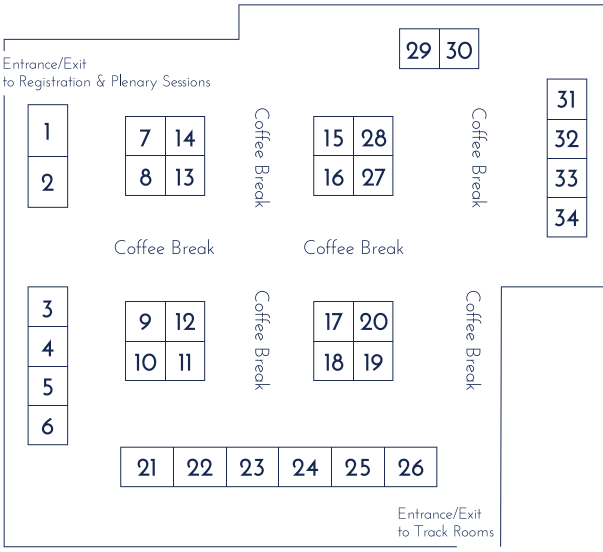

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December 11–14, 2022 *(Tentative)*
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