ICSRS 2021

2021 5TH INTERNATIONAL CONFERENCE ON SYSTEM RELIABILITY AND SAFETY

NOVEMBER 24-26, 2021 | PALERMO, ITALY

TECHNICAL CO-SPONSORED BY IEEE Reliability Society

SUPPORTED BY

UNIVERSITÉ DE LORRAINE

A. JAMES CLARK SCHOOL OF ENGINEERING
CALCE | CENTER FOR ADVANCED LIFE CYCLE ENGINEERING

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ICSRS 2021-November 24-26, 2021 in Palermo, Italy

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Conference Committees

ICSRS 2021-November 24-26, 2021 in Palermo, Italy, UTC/GMT+1

Conference General Chairs

Michael Pecht, Center for Advanced Life Cycle Engineering at the University of Maryland, USA

Enrico Zio, Mines Paristech, France and Politecnico di Milano, Italy

Steering Committees

TANG Loon Ching, National University of Singapore, Singapore

Rui Kang, Beihang University, China

Yi Ding, Zhejiang University, China

Program Co-chairs

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Francesca Saglietti, University of Erlangen-Nuremberg, Germany

Emanuele Borgonovo, Bocconi Business School, Italy

Sebastian MARTORELL, Universitat Politècnica de València, Spain

Jin Wang, Liverpool John Moores University, UK

Publicity Co-chairs

Xiaoping Du, Missouri University of Science and Technology, USA

Salah Bourennane, Ecole Centrale Marseille, France

Conference Treasurer

Wei Pan, Southwest Jiaotong University, China

Publication Chair

Jicheng Gu, Southwest Jiaotong University, China

Welcome Message

ICSRS 2021-November 24-26, 2021 in Palermo, Italy, UTC/GMT+1

2021 5th International Conference on System Reliability and Safety (ICSRS 2021) will be held during November 24-26, 2021 in Palermo, Italy. ICSRS 2021 is Technical Co-Sponsored by IEEE Reliability Society (Italy Chapter).
Under the current situation of novel coronavirus around the world, most of countries put lockdown in cities to prevent the pandemic of spreading out. And this year, we are so fortunate that we could have this conference both onsite and virtually.

ICSRS is an annual event which aims at a key theme on System Reliability and Safety. It will feature world-class plenary speakers, major technical symposiums, industry and academic panels, workshops, tutorials and invited tracks. In the past years, ICSRS has become an international leading conference in System Reliability and Safety field. It was held in many large capital cities, such as Rome, Paris, Milan, Barcelona.
ICSRS 2021 includes keynote & Invited speeches and parallel technical tracks. The chairman and keynote speakers played a great role in conducting the proceedings of the conference and on behalf of the conference committee, we would like to express sincere thanks for your long-term support and help on our work. We were grateful for the reviewers, who had also been very helpful in efficiently reviewing the manuscripts and made valuable suggestions for the authors to improve their work. At the same time, we also extended our heartfelt thanks to the understanding and support of every author.
We are pleased to know that all conference participants found the discussions fruitful, and enjoyed the opportunity to pursue future collaborations. We look forward to seeing all of you again next year at the conference.

General Information

ICSRS 2021-November 24-26, 2021 in Palermo, Italy, UTC/GMT+1

Venue Location

Contact Person: Chiara Buonamente (direttore) - Calogero Fantauzzo (booking)

Contact Number: 0039 091 77 81 610

Email address: booking@hotelpalazzositano.it

Hotel address: Via Vittorio Emanuele, 114 - 90141 Palermo

Web: https://www.hotelpalazzositano.it/en/#section-id-1556006950056

Time Zone: UTC/GMT+1

Note: ZOOM conference rooms will be open 30 mins before scheduled time.

The opening ceremony and keynote speeches will be broadcast on ZOOM

ZOOM instruction: www.icsrs.org/ZOOM+Guideline.docx

Zoom Download: https://zoom.us/ **Author in China:** https://zoom.com.cn/download

Tips: Please unmute audio and start video while your presentation.

It’ s suggested to use headset with microphone or earphone with microphone.

Online Conference Zoom Room ID Number

Date	Arrangement	Zoom Link
Nov. 24	Zoom testing for online presenters	Zoom Link: https://zoom.us/j/97008300466 Password: 112426 Rename as: Paper ID-Name; Listener- Name; Keynote-Name; Committee-Name
Nov. 25	Keynote & Invited Speeches; Oral Sessions	
Nov. 26	Oral Sessions	

General Information

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Attention

♣ Due to COVID-19 Pandemic, delegates must show health QR attend conference. For health consideration, please wash hands before meals and please use serving chopsticks and serving spoon during meals.

♣ Please take care of your belongings in public area. For your personal and property safety, delegates are suggested to wear representative card during conference and not to lend it to those unconcerned to enter event rooms. Conference does not assume any responsibility for loss of personal belongings of participants.

♣ Don’ t stay too late in the city, don’ t be alone in the remote area. Be aware of the strangers who offer you service, signature of charity, etc., at scenic spots. You can search more Tourist Information and Security tips online.

Devices Provided by the Conference Organizer

Laptops (with MS-Office & Adobe Reader); Projectors & Screen

Materials Prepared by the Presenters

Onsite Presentation: PowerPoint or PDF files. Please copy your slides to the desktop 10mins before your session.

Online Presentation: PowerPoint or PDF files. Please install ZOOM in advance and join our online session on time.

Duration of Each Presentation

Keynote Speech: 40 Minutes of Presentation including Q&A.

Invited Speech: 25 Minutes of Presentation including Q&A.

Regular Oral Presentation: 15 Minutes of Presentation including Q&A.

Note:

The regular oral presentation time arrangement is for reference only. In case any absence or some presentations are less than 15 minutes, please join your session before it starts.

An excellent presentation will be selected from each session which will be announced and awarded an excellent presentation certificate.

Conference Schedule

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Nov. 24: Online test timetable and online sign-in

Time	Arrangement	Zoom Link
Nov. 24 9:00-11:00	**Test for Online Presenters** R021, R033, R057, R081, R088, R091, R020, R058, R019-A, R036-A, R039, R052, R070, R056, R048-A, R060, R017, R032, R038, R046, R042, R061, R066, R031, R023, R025, R026, R027, R055, R062, R065, R068-A, R024, R022, R074-A, R029, R043, R073-A, R096-A, R071, R079-A, R072-A, R018, R075-A, R076-A, R082, R083, R085, R093-A, R099-A, R037, R044, R084, R090, R034, R095-A, R098-A, R101-A, R007, R045, R078, R092, R094, R077, R097-A, R100-A, R080-A, R089-A	Zoom Link: https://zoom.us/j/97008300466 Password: 112426 Rename as: Paper ID-Name; Listener- Name; Keynote-Name; Committee-Name
Nov. 24 9:00-12:00	**Test for Online Keynote & Invited Speakers & Session Chairs** **Keynote Speakers:** Prof. Nicola Pedroni, Prof. Michael Beer; Prof. Rui Kang **Session keynote lectures:** Zhiguo Zeng; Umberto Alibrandi; Olga Fink; Yiping Fang; Márcio das Chagas; Luca Podofillini **Session Chairs:** Robert E. Kooij; Ewa Dąbrowska; Iryna Mozgova; Luca PODOFILLINI; Sameer Al-Dahidi	

Conference Schedule

ICSRS 2021-November 24-26, 2021 in Palermo, Italy, UTC/GMT+1

Nov. 25-Venue: Meeting room

Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Host: Prof. Enrico Zio, Politecnico di Milano, Italy	
Time	**Arrangement**
8:00-9:00	**Onsit Meeting Sign-in** Venue: Palazzo Sitano-Meeting room Hotel address: Via Vittorio Emanuele, 114 - 90141 Palermo
9:00-9:10	**Opening Remarks: Prof. Enrico Zio, Politecnico di Milano, Italy**
9:10-9:50	**Keynote Speaker I** Prof. Nicola Pedroni, Politecnico di Torino, Italy Speech Title: Artificial Intelligence, Meta-Modeling and Adaptive Simulation for the Efficient Analysis of the Mathematical Models of Complex, Safety-Critical Engineering Systems, in the Presence of Uncertainties
9:50-10:30	**Keynote Speaker II** Prof. Rui Kang, Beihang University, China Speech Title: Belief Reliability: A New Theory for Reliability Engineering
10:30-11:00	**Coffee Break & Group Photo**

Conference Schedule

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Nov. 25-Venue: Meeting room

Zoom Link: https://zoom.us/j/97008300466 Password: 112426

11:00-11:40	**Keynote Speaker III** Prof. Michael Beer, Leibniz Universität Hannover, Germany; University of Liverpool, UK; Tongji University, China Speech Title: Analysis of Engineered Systems: uncertainties, complexity and quick decision making
11:40-12:05	**Session keynote lecture I** Zhiguo Zeng, Universite Paris Saclay, France Speech Title: What does “being smart” mean to reliability and resilience?
12:05-13:30	**Lunch & Break**
13:30-15:55	**Oral Session 1 – Fault Detection and Maintenance** Session Chair: Concetta Manuela La Fata, Università degli Studi di Palermo, Italy **Session keynote lecture II** Márcio das Chagas, Federal University of Pernambuco, Brazil Speech Title: A Natural Language Processing – based app to support hazard identification in oil refineries R022, R074-A, R029, R043, R073-A, R096-A, R071, R079-A
15:55-16:10	**Coffee Break**

Conference Schedule

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Nov. 25-Venue: Meeting room

Zoom Link: https://zoom.us/j/97008300466 Password: 112426

16:10-18:25	**Oral Session 2 - Abnormal Diagnosis and Detection** Session Chair: Amin Abedi, Politecnico di Milano, Italy R072-A, R018, R075-A, R076-A, R082, R083, R085, R093-A, R099-A

Online Sessions on Nov. 25 / Zoom Link: https://zoom.us/j/97008300466 Password: 112426 - Breakout room	
13:30-15:15 Breakout room	**Online Session A - Reliability Design and Engineering** Session Chair: Robert E. Kooij, Delft University of Technology, Netherlands R060, R019-A, R036-A, R039, R052, R070, R056
15:15-15:30	**Break**
15:30-17:55 Breakout room	**Online Session B - Safety Management and Risk Analysis** Session Chair: Luca PODOFILLINI, Paul Scherrer Institut, Switzerland **Session keynote lecture III** Umberto Alibrandi, Aarhus University, Denmark Speech Title: Risk-informed Digital Twin (RDT) for the built environment R017, R032, R038, R046, R042, R061, R066, R031

Conference Schedule

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Nov. 26-Venue: Meeting room

Zoom Link: https://zoom.us/j/97008300466 Password: 112426

9:00-11:25	**Oral Session 3 - Reliability Analysis and Evaluation** Session Chair: Francesco Di Maio, Politecnico di Milano, Italy **Session keynote lecture IV** Yiping Fang, Université Paris-Saclay, France Speech Title: Prescriptive Analytics of Network Resilience: An Optimization-Based View R037, R044, R084, R090, R034, R095-A, R098-A, R101-A ***(Coffee & drinks will be ready around 10:30, be flexible with the break time.)***
11:25-13:30	**Lunch & Break**

13:30-16:25	**Oral Session 4 - System Security and Evaluation** Session Chair: Ibrahim Ahmed, Politecnico di Milano, Italy **Session keynote lecture V** Luca Podofillini, Paul Scherrer Institute, Switzerland Speech Title: Building Bayesian Belief Networks from operational events and expert judgment: a human reliability analysis application R007, R045, R078, R092, R094, R077, R097-A, R100-A, R080-A, R089-A ***(Coffee & drinks will be ready around 14:30, be flexible with the break time)***

Conference Schedule

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Online Sessions on Nov. 26 / Zoom Link: https://zoom.us/j/97008300466 Password: 112426 - Breakout room	
9:00-11:40 Breakout room	**Online Session C - Fault Diagnosis and Detection** Session Chair: Sameer Al-Dahidi, German Jordanian University, Jordan **Session keynote lecture VI** Olga Fink, Professor of Intelligent Maintenance Systems, ETH Zürich Speech Title: Domain adaptation for intelligent maintenance systems R020, R021, R033, R057, R081, R088, R091, R058, R048-A
11:40-13:30	**Lunch & Break**
13:30-15:45 Breakout room	**Online Session D - Computer and Information Security** Session Chair: Ewa Dąbrowska, Gdynia Maritime University, Poland R065, R023, R025, R026, R027, R055, R062, R068-A, R024

Keynote Speaker

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Prof. Nicola Pedroni
Politecnico di Torino, Italy
Nov. 25, 9:10-9:50 - Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Bio: Nicola Pedroni (B.Sc. Energy Engineering, 2003; M.Sc. and Ph.D. Nuclear Engineering, 2005 and 2010, all from Politecnico di Milano) is an Associate Professor in Nuclear Power Plants at the Energy Department of Politecnico di Torino (Torino, Italy). Before, he has been a (temporary) Associate Professor at the Eléctricité de France (EDF) Chair "System Science & Energetic Challenge" at École CentraleSupélec, Université Paris-Saclay (Chatenay-Malabry, France) (January 1, 2016-April 1, 2017) and an assistant professor in the same university (March 1, 2013-December 31, 2015). During his Ph.D., he visited the Department of Nuclear Science and Engineering of the Massachusetts Institute of Technology (September 2008-May 2009). In March 2018, he received the (Italian) National Academic Qualification to be a Full Professor in the Scientific Disciplinary Area of "Thermodynamics and Nuclear Engineering". In February 2016, he received the (French) Academic Habilitation to Direct the Research in the Scientific Sector "Engineering Informatics, Automatics and Signal Processing" and, in February 2017, the corresponding qualification to be a Full Professor. His research focuses on the study and development of advanced computational methods for the reliability, safety, risk, vulnerability and resilience analyses of complex, safety-critical engineering systems, in presence of uncertainties; in particular: advanced Monte Carlo simulation methods for efficient reliability estimation; computational methods for the Integrated Deterministic and Probabilistic Safety Assessment of dynamic engineering systems; theories and methods for uncertainty representation and propagation; soft-computing techniques for empirical regression modeling; techniques for solving nonlinear, constrained optimization problems;

theories and methods for modeling and simulating the behavior of power transmission networks and interdependent critical infrastructures. He is co-author of 53 papers on international journals, 1 editorial, 31 papers on proceedings of international conferences, 5 chapters in international books and 5 works published as technical reports of international research institutes. He has served as referee more than 20 international journals.

Speech Title: Artificial Intelligence, Meta-Modeling and Adaptive Simulation for the Efficient Analysis of the Mathematical Models of Complex, Safety-Critical Engineering Systems, in the Presence of Uncertainties

Abstract: The response of engineered systems under different conditions can be studied, in general, by means of mathematical models implemented in corresponding computer codes for numerical simulations. In particular, in the analysis of safety-critical systems (such as nuclear power plants, electrical grids, etc.) repeated model simulations are used to identify undesired or abnormal states, which is of paramount importance for optimally designing and operating such systems and defining accident prevention and mitigation actions. For complex systems, this way of proceeding is in general challenging because the corresponding simulation tools are: i) computationally demanding (i.e., they require a long time to run a simulation compared to the available computational resources); ii) high-dimensional (i.e., they involve large number of inputs and/or outputs); iii) black-box (i.e., the mathematical function underlying the input-output relation is not known explicitly and is usually nonlinear); iv) dynamic (i.e., they evolve in time); and v) affected by severe uncertainties (often due to the scarcity of quantitative data available). The presentation will address the above-mentioned issues by proposing advanced combinations of artificial intelligence, meta-modeling and adaptive simulation tools for the efficient analysis of the mathematical models of engineering systems, in the presence of uncertainties. The practical benefits of the presented approaches will be shown with reference to safety-relevant tasks, e.g., the robust estimation of safety margins and the thorough characterization of the failure conditions for critical systems (e.g., nuclear plants).

Keynote Speaker

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Prof. Rui Kang
Beihang University, China
Nov. 25, 9:50-10:30 - Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Bio: Rui Kang is a professor of School of Reliability and Systems Engineering of Beihang University. He is a distinguished professor of the Chang Jiang Scholars Program. He is also the director of Center for Resilience and Safety of Critical Infrastructure (CRESCI) and Sino-French Risk Science and Engineering Lab. He is the founder of Belief Reliability Theory. His main research interests include reliability and resilience for critical infrastructures, system prognosis and health management. He published eight books and more than 200 papers.

Speech Title: Belief Reliability: A New Theory for Reliability Engineering

Abstract: Reliability engineering, as an important approach to fight against product failure, has been challenged by various problems in recent years, especially the inconsistency of metrics and definition, the uncertainty of information and data, and the complexity of product function and structures. Facing these challenges, this keynote will systematically introduce and review a new reliability theory called the belief reliability to cope with these challenges. First, beginning with the origin of reliability theory and engineering, the problems of present reliability theories are summarized as an ask, a dilemma, and a mystery.

Then, through philosophical reflection, we will introduce the theoretical solutions given by belief reliability theory, including three scientific principles, four basic equations, two kinds of reliability experiments, and one mathematical measure and measurement framework incorporating aleatory and epistemic uncertainty. On the basis of above discussion, the basic methods and technologies of belief reliability, namely, belief reliability analysis, top-down design and evaluation, are elaborated and overviewed. Sequentially, several applications of belief reliability such as maintenance and supportability optimization, risk analysis, prognostics and health management are briefly investigated. Finally, we also summarize the contributions and significance of belief reliability theory and make some prospects about future research, aiming to promote the reliability engineering in a more scientific way.

Keynote Speaker

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Prof. Michael Beer
Institute for Risk and Reliability, Leibniz Universität Hannover, Germany
Nov. 25, 11:00-11:40 - Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Bio: Michael is Professor and Head of the Institute for Risk and Reliability, Leibniz Universität Hannover, Germany, since 2015. He is also part time Professor at the Institute for Risk and Uncertainty, University of Liverpool and in Tongji University, China. He obtained a doctoral degree from the Technical University of Dresden and pursued research at Rice University, supported with a Feodor-Lynen Fellowship from the Alexander von Humboldt-Foundation. From 2007 to 2011 Michael worked as an Assistant Professor at National University of Singapore. In 2011 he joined the University of Liverpool as Chair in Uncertainty in Engineering and Founding Director of the Institute for Risk and Uncertainty. He is serving on the Board of Directors (2020-2028) of the International Association for Probabilistic Safety Assessment and Management, and he is a Co-Chair (2020–2023) of the Risk and Resilience Measurements Committee (RRMC) of the ASCE Infrastructure Resilience Division. Michael is an Editor in Chief (jointly) of the Encyclopedia of Earthquake Engineering (Springer), and a Founding Associate Editor of the ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems (2014 to 2020). His further editorial appointments include an Associate Editorship of the International Journal of Reliability and Safety, as well as 13 Editorial Board Memberships including Probabilistic Engineering Mechanics, Mechanical Systems and Signal Processing, Computers and Structures, Structural Safety and Engineering Structures. Michael's research is focused on non-traditional uncertainty models in engineering with emphasis on numerically efficient reliability and risk analysis.

Keynote Speaker

ICSRS 2021-November 24-26, 2021 in Palermo, Italy, UTC/GMT+1

Speech Title

Analysis of Engineered Systems: uncertainties, complexity and quick decision making

Abstract

Engineered systems are often quite complex so that a detailed modeling and analysis for reliability assessment and maintenance planning is very demanding. In addition, uncertainties arising from the complexity and also from, sometimes even unknown, operational, environmental and man-made excitations or hazards undermine the clarity of predictions about the systems behavior and its reliability. Still, we need a technology for a reliable but quick analysis that provides unambiguous and illustrative decision-support for operators and users. The presentation will feature some ideas and methods that could be helpful to provide a basis for quick and informed decisions despite uncertainty and complexity. Dealing with uncertainties in an efficient systems reliability analysis is explained from a conceptual perspective in association with the survival signature approach. The idea of functionality-based systems modeling for quick and effective decision-making is presented for the challenge of maintenance of an aircraft turbine at most reasonable economic and technical effort. The technical ingredients include systems modeling, reliability analysis, and resilience-based decision-making.

Session keynote lectures

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Zhiguo Zeng, Universite Paris Saclay, France

Nov. 25, 11:40-12:05 - Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Bio: Zhiguo ZENG received the Ph.D. degree in reliability engineering from Beihang university in 2016. He is currently an assistant professor at CentraleSupélec, Université Paris-Saclay, France. His research focuses on the characterization and modeling of the failure/repair/maintenance behavior of components, complex systems and their reliability, maintainability, prognostics, safety, vulnerability and security. Dr. ZENG is an author/co-author of more than 50 papers in highly recognized international journals and conferences (including 32 journal papers indexed in Web of Science).

Márcio das Chagas, Federal University of Pernambuco, Brazil

Nov. 25, 13:30-13:55 - Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Bio: Márcio das Chagas Moura is an Associate Professor at the Federal University of Pernambuco (UFPE), Center of Technology and Geoscience, Department of Industrial Engineering, Brazil. He's the research leader at the Center for Risk Analysis, Reliability Engineering and Environmental Modeling (CEERMA - https://sites.ufpe.br/ceerma/), which is a very multi and interdisciplinary lab, where students at all levels carry out their research projects. Indeed, he believes that he and his colleagues have built at CEERMA a quite collaborative and team-working environment to develop rigorous research. At CEERMA, he encourages his students and fellows to establish mutual and meaningful connections, which it is fundamental and paramount to a productive workplace. His research interests include the following major topics: (i) Reliability Engineering, (ii) Risk Analysis, Assessment and Management, and (iii) Modeling, Simulation and Optimization of Production Systems.

Session keynote lectures

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Umberto Alibrandi, Aarhus University, Denmark

Nov. 25, 15:30-15:55 - Zoom Link: https://zoom.us/j/97008300466 Password: 112426 Breakout Room

Bio: Dr. Umberto Alibrandi graduated as PhD in Civil and Environmental Engineering, at the University of Messina, 2006, defending the thesis “Computational Methods in Structural Reliability and Stochastic Mechanics”. Dr. Umberto Alibrandi was postdoctoral researcher at the University of Messina from 2006 to 2008, University of California at Berkeley from September 2008 to May 2009, National University of Singapore from 2013 to 2015, Nanyang Technological University from 2015 to 2017, and Berkeley Education Alliance for Research in Singapore from 2017 to 2018. From 2010 to 2012, Dr. Umberto Alibrandi worked as a Structural Engineer in Italy. Dr. Umberto Alibrandi apply methods of Performance Based Engineering, Structural Reliability, and Risk Analysis, Computational Stochastic Mechanics, Risk informed Decision Support for structures, Machine Learning, and Artificial Intelligence for academia and industry for more than 15 years. His current research interests focus on the development of new data-driven risk-based frameworks, methods, and tools aimed at sustainable and resilient urban communities. This requires incorporating holistically urban systems, energy systems, environmental systems, and human systems. More specifically, to cope with the inherent complexity and uncertainty, Dr. Umberto Alibrandi is developing a novel framework of data-driven uncertainty quantification and risk analysis rooted on the information theory. The framework will be tailored to the deployment of Risk-informed Digital Twins (RDT) for design and management under uncertainty of smart buildings and infrastructures. The tools of the RDT are going to be deployed inside the opensource computational platform OpenAIUQ.

Session keynote lectures

ICSRS 2021-November 24-26, 2021 in Palermo, Italy, UTC/GMT+1

Yiping Fang, Université Paris-Saclay, France

Nov. 26, 9:00-9:25 - Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Bio: Yiping Fang received his Ph.D. degree in Industrial Engineering from École Centrale Paris (ECP), France. He is currently an Assistant Professor in the Chair Risk and Resilience of Complex Systems, Laboratoire Génie Industriel, CentraleSupélec, Université Paris-Saclay, France. He has been the postdoc research fellow at ETH Zurich, Switzerland from 2015 to 2017. His research is highly interdisciplinary and involves leveraging advanced analytical tools, mainly mathematical optimization, risk and decision analysis, and machine learning, to address the risk and resiliency challenges of critical cyber-physical systems (e.g., smart grids, intelligent transportation, and 5G-and-beyond-systems). He has co-supervised 1 postdoc, 8 Ph.D. theses, and has 1 book chapter, over 25 papers published in prestigious JCR journals and over 20 peer-reviewed conference papers. He is also the director of the international master program Risk and Resilience Engineering and Management at CentraleSupélec, University of Paris-Saclay.

Olga Fink, Professor of Intelligent Maintenance Systems, ETH Zürich

Nov. 26, 9:00-9:25 - Zoom Link: https://zoom.us/j/97008300466 Password: 112426 Breakout Room

Bio: Olga Fink has been assistant professor of intelligent maintenance systems at ETH Zürich since October 2018. Olga is also a research affiliate at the Massachusetts Institute of Technology and an Expert of the Innosuisse, Swiss Innovation Agency, in the field of Information and Communication Technology. Olga's research focuses on Intelligent Maintenance Systems, Data-Driven Condition-Based and Predictive Maintenance, Hybrid Approaches Fusing Physical Performance Models and Deep Learning Algorithms, Deep Learning and Decision Support Algorithms for Fault Detection and Diagnostics of Complex Industrial Assets.

Session keynote lectures

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Luca Podofillini, Paul Scherrer Institute, Switzerland

Nov. 26, 13:30-13:55 - Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Bio: Luca Podofillini is a senior scientist at the Paul Scherrer Institute of Switzerland. He has a Nuclear Engineering degree and Ph.D. in Nuclear Engineering from the Polytechnic of Milan (2004). His activities include Human Reliability Analysis research and regulatory support tasks for the Swiss Federal Nuclear Safety Inspectorate. His research addresses the development of quantitative models of human performance in industrial systems, with focus on errors in decision-making, dynamic safety assessment, collection of data in simulated emergencies. He is co-author of about 40 publications on peer-reviewed international scientific journals. He is currently vice-Chair of the ESRA (European Safety and Reliability Association), chair of the Technical Committee for Human Factors in Safety and Reliability and member of the Board of the Human Reliability Analysis (HRA) Society.

Oral Session 1 – Fault Detection and Maintenance - Nov. 25, 13:30-15:55

Session Chair: Concetta Manuela La Fata, Università degli Studi di Palermo, Italy

Venue: Meeting room - Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Session keynote lecture Online 13:30-13:55	A Natural Language Processing – based app to support hazard identification in oil refineries Márcio das Chagas, Federal University of Pernambuco, Brazil Abstract: Oil and gas refineries involve handling and storing hazardous materials, and the uncontrollable release of these substances may lead to catastrophic accidents. In this context, risk studies are aimed at designing either preventive measures to avoid the undesired events or safeguards to mitigate the consequences in case an accident occurs. To that end, risk experts postulate possible leakages, identify their causes and consequences, and finally evaluate and classify the risks into categories. These qualitative risk analyses rely on examination of a variety of engineering, textual documents and attending numerous meetings, which is quite laborious and time consuming, especially for oil refineries that are large, equipment-intensive facilities. Therefore, we here propose to use Natural Language Processing and multiple deep learning models, called Transformers, for aiding some tasks, which are involved in qualitative risk assessments. These techniques can be applied to extract, organize, and classify information from past textual risk studies, and then allow for recognizing patterns. Our idea is to identify the potential consequences of accidents related to the operation of an oil refinery, and to classify each accidental scenario in terms of severity of the consequence and likelihood of occurrence. Thus, it will be possible to reduce the required efforts in completing the early stages of a risk analysis. Moreover, we developed a Hazard Analysis based on Language processing for Oil refineries (HALO), a web app to support risk analyst in identifying and assessing different accident scenarios related to chemical spills in oil refineries. The app was built on valuable information gathered from past risk studies, allowing experts to use that entire source of knowledge in the early stages of QRA. HALO displays visual outputs, including word clouds for the description of similar systems

	found in our database and a bar chart to illustrate the distribution of the potential consequences related to chemical spills in similar systems. These visual outputs summarize the knowledge contained in previous risk studies and allow the user (risk analyst) to gain insight into the analyzed system. Thus, it will be possible to support risk analysts to complete the early stages of a QRA. The proposed method and app were applied to an actual oil refinery and presented very auspicious outcomes.
R022 **13:55-14:10**	Soft Error Detection Through Low-level Re-execution Brent De Blaere, Jens Vankeirsbilck, Jeroen Boydens Presenter: Brent De Blaere, KU Leuven, Belgium Abstract: Nowadays, embedded systems are widely used both in general-purpose as well as in safety-critical applications. Due to technological advances, these embedded systems can operate on extremely small footprints and low voltages. This, however, makes them more susceptible to external disturbances such as electromagnetic interference. These disturbances can cause single event upsets, a bit being flipped inside the microcontroller, which in turn can result in unexpected and unpredictable behavior of the system due to control flow errors or data flow errors. Many software-implemented control flow and data flow error detection techniques have been examined in the past. However, these techniques often require a large amount of devoted CPU registers to work correctly. Not every system is able to devote a large portion of its registers to an error detection technique. This paper proposes DETECTOR: a new low-level re-execution-based technique protecting against both data flow and control flow errors, while using only three CPU registers. The experimental results presented in this paper are promising, showing that DETECTOR is able to significantly increase the reliability of the system.
R074-A **14:10-14:25**	Performance Shaping Factors for Fire Human Reliability Analysis of Korean NPPs Sun Yeong Choi Presenter: Sun Yeong Choi, Korea Atomic Energy Research Institute, South Korea

	Abstract: Fire hazard is recognized as a major challenge to safe operation of Nuclear Power Plants (NPPs). Therefore, many studies have been performed for quantification of fire risk in NPPs. In Korea, several projects had been performed to establish a fire Probabilistic Safety Assessment (PSA) process and a Human Reliability Analysis (HRA) process for the fire PSA at Korea Atomic Energy Research Institute (KAERI). Especially, for a fire HRA, a guidance for a fire HRA based on K-HRA method was developed. K-HRA method is a standard method for HRA of a domestic level 1 PSA developed by KAERI. To this end, the development policy of the guideline was established to reflect the recent research trend of NUREG-1921 in an effort to meet the requirements of ASME/ANS PRA Standard. For a detailed quantification of Human Error Probabilities (HEPs) with the K-HRA method, new operator actions are developed and the Performance Shaping Factors (PSFs) of K-HRA were modified to consider a fire situation mentioned in NUREG-1921 and a specific fire situation of Korean NPP based on Main Control Room (MCR) operators' interview.
R029 **14:25-14:40**	Model-based Development of a Diagnostic Algorithm for Central Inverter Thermal Management System Fault Detection and Isolation Lapo Cheli, Carlo Carcasci Presenter: Lapo Cheli (University of Florence – Department of Industrial Engineering (DIEF)), Italy Abstract: This paper presents a method for developing an on-field diagnostic algorithm for a Thermal Management System (TMS) of a Central Inverter (CI) for solar fields. The first step relies on an in-depth qualitative analysis, making use of the physical knowledge of the system, through the Fault Tree Analysis (FTA), whose outcome is an inferential isolation tool called Fault Signature Matrix (FSM), which univocally links every fault to a set of symptoms detected during the on-field monitoring. A quantitative fault-to-symptoms sensitivity study is performed using a stationary thermodynamic model, previously developed by the authors, to simulate the system under faulty operating conditions. Four faults are simulated, like heat exchanger fouling or cold plate blockage, and in addition, the variation of the maximum junction temperature of the electronic components is

	examined to assess the impact of the analyzed faults on the performance of the plant's thermal management system. The resilience of the FSM is evaluated by testing several fault magnitudes and symptom thresholds and thus a final modified matrix is obtained.
R043 **14:40-14:55**	Power Unavailability Reduction in Distribution Grid Fault Management with Entropy Minimization Michele Garau and Bjarne E. Helvik Presenter: Michele Garau, SINTEF Energy Research, Norway Abstract: Smart automation is acquiring a high importance in current distribution systems. The high number of buses, the radial topology, the small number of sensors and automated devices, require new approaches in managing fault conditions. These approaches must be able to deal with a high level of uncertainty of the state of the system and the measurement data. In this paper a novel method for fault location and isolation is proposed, which is based on the principle of entropy minimization. The algorithm builds a switch operation strategy which is able to locate the fault in a minimum number of manoeuvres, and therefore to reduce the impact of blackouts in terms of power unavailability. The application of the method on different distribution network topologies, with different levels of automation in terms of fault indicators and remotely controlled switches, demonstrates the potential of the method for distribution system analysis and supporting system automation planning.
R073-A **14:55-15:10**	Comparison of supervised and unsupervised learning-based sensor fault detection model in nuclear power plant emergencies Jeonghun Choi, Seung Jun Lee Presenter: Jeonghun Choi, Ulsan national institute of science and technology (UNIST), Rep. of Korea Abstract: In the nuclear power plant, the plant operation is controlled by plant operators in the main control room with the instrumentation of critical signals and control based on the measurement. The importance of signals is more crucial in an

	emergency situation. Initiated with severe irregular failures, the reactor gets tripped in the emergency situation by automated signal and dramatic parameter changes occur. During these situations, operators are hard to recognize the sensor defects, thus, wrong sensor values can cause critical human errors or automation malfunction. In this research, neural network-based sensor fault detection systems have been suggested with two strategies: supervised learning and unsupervised learning. First, the sensor fault detection model was developed with a long short-term memory network which is a sort of recurrent neural network. The consistency index was suggested for quantifying the sensor soundness in emergency situations. For the training set, each parameter is labeled with a consistency index with every time step. The performance tests were performed with processing the output consistency index of untrained data. The other strategy is autoencoder-based unsupervised learning. Autoencoder is a combination of encoder and decoder, thus, it extracts the feature from input and reconstructs the output. By analyzing the residuals, the signal status can be classified. Suggested two models have different advantages and disadvantages in terms of robustness and accuracy.
R096-A **15:10-15:25**	Making Fault Prognostics more Interpretable: a LIME-based Approach for the Identification of the Degradation Mode Giovanni Floreale Presenter: Giovanni Floreale, Politecnico di Milano, Italy Abstract: A limiting factor for the application of predictive methods based on Artificial Intelligence (AI) for Condition-Based Maintenance (CBM) and Predictive Maintenance (PM) to safety-critical systems (e.g. in the nuclear, chemical, aerospace, transportation industries) is the causality opaqueness of their outcomes. Not understanding the derivation of the outcomes of AI-based models can lead to taking as good some which are incorrect and potentially harmful because of biases or the presence of outliers in the training set. In practice, it is necessary to be able to question, understand and trust AI models, and for this interpretability methods are being developed. This work proposes a local, post-model, model-agnostic method to explain the outcomes of AI models for predicting the

	Remaining Useful Life (RUL) of industrial equipment. The final objective is the identification of the degradation phenomenon that will lead to failure in order to quantify the level of risk and optimize maintenance interventions. The developed method is based on the Local Interpretable Model-agnostic Explanations (LIME method), which allows identifying the features most relevant for the model prediction. The developed method has been validated considering a synthetic case study simulating the behaviour of a monitored component affected by two different degradation phenomena. We have developed an Artificial Neural Network (ANN) for RUL estimate and applied the developed interpretability method to identify the degradation phenomenon that will lead to failure.
R071 **15:25-15:40**	Differences between the aircraft accident probabilistic models Justyna Cybowska Presenter: Justyna Cybowska, National Centre for Nuclear Research, Poland Abstract: Hazardous facilities like nuclear power plants and other nuclear facilities have to meet many safety requirements among which the aircraft crash frequency is also considered. Many models of aircraft crash risk exist and are in use in different countries not only for the needs of hazardous facilities but also to designate safety zones around airports. In this contribution, three models of third-party risk (Byrne, DOE, NATS) were analyzed and the result of the aircraft crash probability they give, compared. It was shown with use of the statistical tests (Friedman Test and Nemenyi Test) that the differences between aircraft crash probabilities calculated from different models are significant.
R079-A **15:40-15:55**	Modeling and analysis of the bounce process in flexible multi-body relays under load conditions Lanxiang Liu, Enrico Zio, Wenying Yang Presenter: Lanxiang Liu, Politecnico di Milano, Italy; Harbin Institute of Technology, China Abstract: Relays are widely used in power equipment and systems to control and transform power. The contact behavior during

	switching load conditions greatly affects the relay's reliability. The traditional dynamic analysis methods of the relay bounce are based on the rigid body assumption, which assumes that no deformation occurs during the movement of the components. However, the contact systems of modern relays are usually designed as flexible spring-rod contact types. Then the analysis method with rigid body assumption is unable to capture the bounce process accurately. To address this issue, a new rigid-flexible coupling calculation method that couples rigid body motion, bending deflection, and impact process of the flexible component is proposed in this paper. The dependences of some key factors such as current, structural parameters and material parameters on the contact condition are analyzed. The advantages of the proposed rigid-flexible coupling model are: 1) it involves the calculation of multi-physical fields, including electrical field, magnetic field, thermal field, and mechanical field for a relay; and 2) it is computationally efficient and capable of simulating the dynamic bounce process. Analysis carried out by this method on a real relay shows that the bouncing tendency of the contact reed is determined by the resultant pressure and the impact effect in the contact area.

Oral Session 2 – Abnormal Diagnosis and Detection - Nov. 25, 16:10-18:25

Session Chair: Amin Abedi, Politecnico di Milano, Italy

Venue: Meeting room - Zoom Link: https://zoom.us/j/97008300466 Password: 112426

R072-A **16:10-16:25**	Identifying the Vulnerabilities of Power Systems under Uncertainties: An Optimization-Based Approach Amin Abedi, Franco Romerio and Enrico Zio Presenter: Amin Abedi, Politecnico di Milano, Italy Abstract: With the integration of renewable and the extension of the uses of electricity, today's power systems are exposed to a growing level of uncertainties in production and demand, so that planning to enhance their robustness in the face of uncertain operational parameters has become a must. This paper frames a multilevel optimization problem and proposes its solution to identify the vulnerabilities of power systems subject to uncertainties. Unlike the conventional bilevel optimization problems for the N-k contingency analysis, the proposed model immunizes the solutions of vulnerability assessment against all possible realizations of the involved uncertainty. To do so, a new level is added to the conventional bilevel optimization problem trying to maximize the damage, in terms of the amount of involuntary load shedding in the power system. This setup is formulated as a mixed-integer trilevel nonlinear program that is non-convex and NP-hard. Then, the proposed trilevel program is transformed into a one-level mixed-integer linear program (MILP) using duality theory and some proposed linearization techniques. The effect of the conventional linearization techniques and our proved lemma on the computational tractability of the proposed final MILP model are also compared. Numerical results on two IEEE systems and a real 400-kV transmission network demonstrate the performance of the proposed MILP for vulnerability assessment under uncertainties. The comparative results show that the

	reported damage measured in terms of load shedding for the DCOPF-based approach is always optimistic without considering the operational uncertainties.
R018 **16:25-16:40**	Maintenance Practice Performance Assessment of Hydraulic Machinery: West Balkan Meta-Statistics and Energy-Based Maintenance Paradigm Orošnjak Marko Presenter: Orošnjak Marko, Faculty of Technical Sciences, Serbia Abstract: As a consequence of accepting the Green Deal initiative, sustainable maintenance attracted significant attention. However, observation of low market intelligence and lack of sustainable goal-oriented practice has been reported. The article proposes the Energy-Based Maintenance (EBM) paradigm to fulfil the needs of sustainable manufacturing philosophy. The EBM implicitly consists of two concepts: Functional-Productiveness (FPC) and Comparative Functional Dynamics (CFD). Namely, the core of FPC is to propose a new view in understanding the nature of functionality by delineating static (maintenance) events (e.g., total failure, stoppage, etc.) from dynamic (process) events (e.g., quasi-faults, leakage, degradation). The CFD uses FPC and dynamic (process) events and acts as a catalyst in reducing noise in feature extraction by comparing system dynamics and energy consumption. Demonstration on a case study of proposed EBM practice is conducted and used as a measure of comparison with traditional maintenance practices (policies). However, the results show a reduction in oil waste and energy consumption at the cost of increasing inspection and stoppages.
R075-A **16:40-16:55**	Abnormal State Diagnosis Based on Important Parameters Using Explainable Model Ji Hyeon Shin and Seung Jun Lee Presenter: Ji Hyeon Shin, Ulsan National Institute of Science and Technology, Republic of Korea Abstract: A nuclear power plant (NPP) is a complex power generation system where safety is a top priority. More than 200

	abnormal situations may occur from various components constituting an NPP. When an abnormal situation occurs, operators have to conduct an appropriate abnormal operating procedure to mitigate it. For this, they check that numerous plant parameters satisfy the entry conditions in the procedure. This process can be burdensome for operators, which can increase human error. Recently, deep learning techniques have been studied to support this operator diagnosis. In this regard, we approached to provide reliable diagnostic information to the operator by interpreting the deep learning model. This study interpreted a convolutional neural network trained to classify 10 NPP states using explanation techniques such as saliency mapping. And we conducted a visual classification from the trend of parameters that are selected based on the calculated classification reason of the model. As a result, it was confirmed that humans can classify the 10 NPP states only with a few parameters selected by model explanation. In conclusion, we can be expected to improve NPP safety through the reduction of human error by making the operator diagnosis more efficiently.
R076-A **16:55-17:10**	Multi Abnormal State Diagnosis Model Using Convolutional Neural Network and One-Vs-Rest Classifier Seung Gyu Cho and Seung Jun Lee Presenter: Seung Gyu Cho, Nuclear engineering, Ulsan National Institute of Science and Technology, South Korea Abstract: In the main control room of nuclear power plant, there are hundreds of indicators which receive data from tens of thousands of components. In this regard, some abilities are required from the operator when an abnormal condition occurs. Both understanding dynamic conditions with a huge number of indicators and strong mentality within a limited time. These requirements are likely to cause human errors of operators. Multi abnormal states, which are combination of single abnormal condition, wasn't considered for abnormal detection, although it is harder to diagnose than general single abnormal states. Recent studies also have focused on a single abnormal diagnosis. This study introduces abnormal states diagnosis model, containing multi abnormal states diagnosis, using convolutional neural network and one-vs-rest (OVR) classifier. Training input consists of mainly 1 normal state and 9 single abnormal states. Two sorts of approaches are suggested in this study. First, all

	abnormal data contains present value and the change rate from the past. Second, multi abnormal states are diagnosed by mainly multi OVR classifier for multi-label classification. Research result shows that an efficient way to diagnosis multi abnormal states with high accuracy and reliability. It can get ready for not only general abnormal diagnosis but also multi abnormal diagnosis to reduce miss diagnosis.
R082 **17:10-17:25**	Abnormality diagnosis in NPP using artificial intelligence based on image data Sang Hyun Lee, Sang Won Oh, Hye Seon Jo, Man Gyun Na Presenter: Sang Hyun Lee, Chosun university, Republic of Korea Abstract: Accidents in Nuclear Power Plants (NPPs) can occur for a variety of causes. However, among these, the scale of accidents due to human error can be greater than expected. Accordingly, researches are being actively conducted using artificial intelligence to reduce human error. Most of the research shows high performance based on the numerical data on NPPs, but the expandability of researches using only numerical data is limited. Therefore, in this study, abnormal diagnosis was performed using artificial intelligence based on image data. The methods applied to abnormal diagnosis are the deep neural network, convolution neural network, and convolution recurrent neural network. Consequently, in nuclear power plants, it is expected that the application of more methodologies can be expanded not only in numerical data but also in image-based data.
R083 **17:25-17:40**	System and Component anomaly detection using LSTM-VAE Ji Hun Park, Hye Seon Jo, Man Gyun Na Presenter: Ji Hun Park, Chosun university, Republic of Korea Abstract: In the event of an accident at a nuclear power plant, the operators have to take appropriate actions after carrying out the diagnosis of the accident. However, the accident diagnosis can cause the human error because complex procedures have to be performed quickly within a limited time. Accordingly, researches using artificial intelligence are actively being conducted to

	reduce the occurrence frequency of human errors that may occur in diagnostic tasks. Most studies use a supervised learning strategy to assist operators in diagnostic tasks using artificial intelligence. However, there is a problem that the supervised learning strategy cannot be handled properly when untrained data is input. Therefore, this paper aims to provide information to operators by adopting an unsupervised learning strategy that does not cause such a problem. Therefore, we intend to detect abnormalities in the systems and components of nuclear power plants by utilizing long short-term memory variational autoencoder, an artificial intelligence methodology. It is expected that the results of detecting anomalies in systems and components will help operators in diagnosing and mitigating accidents.
R085 **17:40-17:55**	Damage Detection in Truss Structures supporting pipelines and auxiliary equipment in power plants Ali Eftekhari Milani, Piero Baraldi, Antonio Palermo, Alessandro Marzani, Enrico Zio Presenter: Ali Eftekhari Milani, Politecnico di Milano, Italy Abstract: In this work we propose an automatic damage detection procedure for truss structures. The procedure exploits the natural frequencies of the structure, which can be estimated from vibrational signals measured by sensors, and provides as output the classification of the structure state as healthy or damaged. The approach developed for anomaly detection is based on the use of Principal Component Analysis (PCA) for the reconstruction of the natural frequencies as they should be in a healthy truss structure. Then, the occurrence of damage is detected by applying the Q-statistic test to the differences (residuals) between the observed natural frequencies and their values reconstructed by the PCA model. The proposed damage detection strategy is applied to a synthetic dataset containing the natural frequencies of healthy and damaged truss structures obtained by finite element simulations. The frequency distributions account for structural properties and boundary conditions variability, possibly introduced by variation in the structure operational conditions (e.g., ambient temperature, fluid flow, environmental noise). The obtained results show that the proposed model is able to correctly recognize the state of the truss structure with a limited number of false and missed alarms.

R093-A **17:55-18:10**	Economic Service Losses in Accidental Scenarios of Integrated Road-Power Infrastructures with Hybrid Fleets of EVs and ICVs Lida Naseh Moghanlou, Francesco Di Maio and Enrico Zio Presenter: Lida Naseh Moghanlou, Politecnico di Milano, Italy Abstract: Electric Vehicles (Evs) are expected to contribute substantially to the energy transition. However, reliance on Evs must come with the guarantee that the integrated of road-power infrastructure is capable of providing the required service level, considering disruption conditions, due for example to accidents or traffic jams. In this paper, we propose a metric to quantify the economic service losses, related to delays that vehicles may incur in different accidental scenarios. We measure the service level as the ratio between the increase in travel time spent along the origin-destination routes of the road network due to a disruption and the corresponding expected time in nominal conditions: the lower the service level, the greater the capability of road-power infrastructure of withstanding such disruption. Then, to assess the associate economic losses a conservative hypothesis is made of a linear relationship between delays and costs. To exemplify the calculation of the service loss metric and related costs, we consider a benchmark road-power infrastructure in New York state and assume a mixed fleet of Evs and Internal Combustion Vehicles (ICVs), with different Evs penetration levels and under accidental scenarios of different magnitudes. Results show that the futurable increase of Evs penetration may not be so challenging with respect to the service level requirements satisfaction, provided that the power system for Evs charging is capable of adapting to demand increase.
R099-A **18:10-18:25**	Process Planning and Scheduling in Reconfigurable Manufacturing Systems Using Hybrid Simulation-based Optimization Mei Chen, Enrico Zio Presenter: Mei Chen, Politecnico Di Milano, Italy Abstract: The ongoing fourth industrial revolution (industry 4.0) draws great interests from academy and industry, as it can provide desired flexibility and adaptability to changing customer demands and manufacturing environments, to gain more profits within

	tighter energy constraints. To this aim, the concept of Reconfigurable Manufacturing System (RMS), consisting of changeable structures, has been applied successfully in the automobile manufacturing industries [1]. Incorporating advanced techniques of industry 4.0, such as smart sensors, simulation and system integration, into RMS is promising to provide desired scalability and flexibility for producing different part families with less investment and higher efficiency. However, both process planning and scheduling of RMS are not trivial, not only because of the uncertainties involved, like demand changes and machine outages, but also because of the changeable structures of machines and manufacturing lines. In fact, process planning and manufacturing scheduling interact with each other and are mutually implicated [2]. Then integrated planning and scheduling (IPS) of RMS should improve system flexibility while making it robust to disturbances during the manufacturing process, e.g., equipment availability, and outside the RMS, e.g., product demands. Several works already investigate IPS of RMS [3-5]. Yet, there is little research on IPS of RMS under uncertainties. Besides that, the application of smart sensors and actuators to achieve real time monitoring and control of manufacturing process, the adoption of advanced control paradigms, e.g., model predictive control (MPC) for improving responsiveness and robustness of RMS, have not been considered. This work investigates the IPS of RMS under uncertainties. A hybrid model of a RMS is set up, while the corresponding manufacturing process, controlled by MPC, is simulated. A genetic optimization algorithm is used for minimizing the cost and manufacturing cycle under given energy constraints.

Online Session A – Reliability Design and Engineering - Nov. 25, 13:30-15:15

Session Chair: Robert E. Kooij, Delft University of Technology, Netherlands

Breakout Room: Zoom Link: https://zoom.us/j/97008300466 Password: 112426

R060 **13:30-13:45**	The Recoverability of Network Controllability Anqi Chen, Sun Peng, Robert E. Kooij Presenter: Robert E. Kooij, Delft University of Technology, Netherlands Abstract: Network recoverability refers to the ability of a network to recover to a desired performance level after suffering topological perturbations such as link failures. The minimum number of driver nodes is a typical metric to denote the network controllability. In this paper, we propose closed-form analytic approximations for the minimum number of driver nodes to investigate the recoverability of network controllability under link-based perturbations in two scenarios: 1) only the links which are damaged in the failure process can be recovered and 2) links can be established between any pair of nodes that have no link between them after the failure process. Results show that our approximations fit well with simulation results both in synthetic networks and real-world networks, such as swarm signaling networks and some communication networks.
R019-A **13:45-14:00**	Optimal reliability design of one component out capability Kyungmee O. Kim and Sridhanya Gangapuram Presenter: Kyungmee O. Kim, Konkuk University, Korea Abstract: We consider one component-out-design in which the surviving components share the load of the failed component for completing the mission in case one component shuts down safely, without causing the entire cluster failure. One such example is the one engine-out-design used in a propulsion system of a launch vehicle to generate a required thrust. To model

	the reliability of one component-out-design based on an (n–1)-out-of-n load sharing system, it is required to relate (1) between the failure rates of components having different design rated loads, and (2) between the failure rates of a component functioning at different operational loads. To do this, previous research assumed that the component lifetime follows an exponential distribution for a given design load. In this paper, we present a model for determining the optimal number of components to maximize the system reliability when each component for a given design load follows a general lifetime distribution. Then the rocket propulsion system is considered to illustrate the proposed model under the assumption that each engine follows a Weibull lifetime distribution. The result shows how the one engine out capability improves the system reliability.
R036-A **14:00-14:15**	Extended Matrix Approach for High Order Partial Differential Calculus and Its Application to Reliability Engineering Koki Shoji Presenter: Koki Shoji, Tokyo City University, Japan Abstract: This paper proposes a new way of executing high-order partial differential calculus using square matrices and demonstrates an important application to the reliability engineering field. The existing matrix approach for first- and second-order differential calculus prevents an exponential increase in computation time of the post-expression obtained by partial differential calculus and realizes a linear time increase instead. This approach is a breakthrough for solving computation problems not only in reliability engineering fields, but also all science and engineering fields, because partial differential calculus is essential to and commonly used in almost all of them. However, the existing approach can only be applied to first and second-order partial differential calculus. Much higher order partial differential derivatives are out of its scope. This paper first extends the matrix approach to third- and higher-order partial differential calculus. The proposed method is used to compute the k-th order joint reliability importance of system, which is a key index in reliability engineering. Our matrix approach is especially useful when the system has a large number of components, as in the case of communications systems.

R039 **14:15-14:30**	Belief Reliability Modeling and Analysis for the Three-Grid Ion Thruster Shi-Shun Chen, Xiao-Yang Li, Bo-Yuan Li and Jing Li Presenter: Shi-Shun Chen, Beihang University, China Abstract: The ion thruster is one of the most widely used electric propulsion thrusters, and its failure can directly affect the success of deep-space exploration missions. Therefore, the ion thruster is always required with extremely high reliability. However, few researchers thoroughly analyze the influence of internal and external parameters on reliability, which makes it difficult to provide guidance for reliability improvement. In this paper, based on reliability science principles, a reliability model considering performance degradation and multi-source uncertainties is established for three-grid ion thrusters. Firstly, the electron backstreaming limit (EBL) is determined as the key performance parameter based on functional principles and the performance margin model is constructed. Then, the degradation model considering sputter erosion is established through the response surface methodology (RSM). Furtherly, we analyze the sources of uncertainties and quantify uncertainties with probability distributions. Finally, the reliability model is established. A case study of a xenon ion thruster is conducted to perform reliability and sensitivity analysis. The results show that the proposed model can quantify reliability by given internal and external parameters and provide guidance for the designers to meet high reliability requirements.
R052 **14:30-14:45**	Three-state Markov chain based reliability analysis of complex traction power supply systems Wei Zuo and Kang Li Presenter: Wei Zuo, University of Leeds, UK Abstract: The reliability of traction power supply systems (TPSSs) is an important consideration in railway electrification and development of high-speed rail. The state analysis of the whole system and individual components often involves the construction of an appropriate system model. The Markov chain has been widely used to evaluate random processes

	quantitatively and is suitable for the reliability analysis of complex systems with multiple failure modes. A challenge with the Markov chain approach is the curse of dimensionality and its computational complexity increases exponentially with the number of system components. This paper proposes to use a three-state model and system regionalization based on the specific structural features of the TPSS. The failure probability of TPSS over time is analyzed and a new simplified method to compute the average system availability index is developed to evaluate system reliability. Simulation studies confirm that the proposed approach can derive a rich set of reliability indexes, and the reliability of TPSSs can be effectively evaluated.
R070 **14:45-15:00**	Dynamic reliability assessment framework for Integrated Energy Systems based on the improved universal generating function Lixun Chi, Huai Su, Enrico Zio and Jinjun Zhang Presenter: Lixun Chi, China university of petroleum Beijing, UK Abstract: With the development of science and technology in the field of energy, the concept of Integrated Energy System (IES) has attracted more and more researchers' attention. However, it is difficult to evaluate the reliability of the coupled energy system due to the complex systems structure and dynamics in subsystems. This leads to heavy computational burdens for evaluation processing. To overcome this gap, in this paper, a novel systematic reliability assessment framework is proposed to analyze the dynamic reliability of IESs. The data-driven model and improved universal generating function are combined in this method. The components' random behavior is represented by improved universal generating function (IUGF) models. All these IUGF models are aggregated by an operator to build the system IUGF model. The operator is defined as an IES model which is described by a data-driven model. The efficiency and accuracy are validated by comparing the results from the proposed method with that from Monte Carlo simulation. A case study of a realistic bi-directional IES is carried out to demonstrate the effectiveness of the proposed method. The results indicate that the role of P2G is becoming more and more important in IESs with the increasing penetration level of renewable sources. The synergism of P2G and energy storage devices has the best effect on improving the system's reliability.

R056 **15:00-15:15**	Software Reuse Exploits in Node.js Web Apps Tuong Phi Lau Presenter: Tuong Phi Lau, University of Information Technology, Vietnam Abstract: The npm ecosystem has the largest number of third-party packages for making node.js-based web apps. Due to its free and open natures, it can raise diversity of security concerns. Adversaries can take advantage of existing software APIs included in node.js web apps for achieving their own malicious targets. More specifically, attackers may inject malicious data into its client requests and then submit them to a victim node.js server. It then may manipulate program states to reuse sensitive APIs as gadgets required in the node.js web app executed on the victim server. Once such sensitive APIs can be successfully accessed, it may indirectly raise security threats such as code injection attacks, software-layer DoS attacks, private data leaks, etc. For example, when the sensitive APIs are implemented as pattern matching operations and are called with hard-to-match input string submitted by clients, it may launch application-level DoS attacks. In this paper, we would like to introduce software reuse exploits through reusing packages available in node.js web apps for posing security threats to servers. In addition, we propose an approach based on data flow analysis to detect vulnerable npm packages that can be exposed to such exploits. To evaluate its effectiveness, we collected a dataset of 15,000 modules from the ecosystem to conduct the experiments. As a result, it discovered out 192 vulnerable packages. By manual analysis, we identified 156 true positives of 192 that can be exposed to code reuse exploits for remotely causing software-layer DoS attacks with 128 modules of 156, for code injection with 18 modules, and for private data leaks including 10 vulnerable ones.

Online Session B – Safety Management and Risk Analysis - Nov. 25, 15:30-17:55

Session Chair: Luca PODOFILLINI, Paul Scherrer Institut, Switzerland

Breakout Room: Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Session keynote lecture Online 15:30-15:55	Risk-informed Digital Twin (RDT) for the built environment Umberto Alibrandi, Aarhus University, Denmark Abstract: The Digital Twin (DT) is a virtual replica of realworld buildings, processes, structures, people, systems created and maintained in order to answer question about its physical part, the Physical Twin (PT). In the case of the built environment, the PT is represented by the smart buildings and infrastructures. Full synchronization between the DT and the PT will provide a perpetual learning process and updating between the two twins. To take into consideration the multiple unavoidable sources of uncertainty during the lifecycle, it has been recently introduced a novel concept of DT, called Risk-informed Digital Twin (RDT) ([1]–[3]). While In the DT the model predictions are developed through data-driven tools and algorithms, in the RDT the several sources of uncertainty are described through integrated methods and tools of Statistics, Random Vibrations, Risk Analysis ([4], [5]) and Machine Learning ([6]–[9]). More specifically, the RDT incorporates as a core: (i) a novel framework of data-driven Uncertainty Quantification and Risk Analysis rooted on the information theory, called AIUQ ([10]–[14]) (ii) the framework of Sustainable and Resilient Based Engineering (SRBE) introduced in [3], and thought as a first step toward the extension of performance-based engineering (PBE) approaches ([15], [16]) to Socio-Ecological-Technical systems under uncertainty. In the talk we will discuss the potential of this potentially disruptive technology, toward the achievement of the UN Sustainable Development Goals [17] with reference to the built environment. Some selected but representative examples will be shown, including the SinBerBest [18] Office in Singapore where a preliminary version of the RDT has been already deployed and it is currently working

R017 **15:55-16:10**	An Approach of a Safety Management System for Highly Automated Driving System Marzana Khatun, Florence Wagner, Rolf Jung, Michael Glaß Presenter: Marzana Khatun, Kempten University of Applied Sciences, Germany Abstract: To allow a vehicle with highly automated driving functions to operate on the road the overall safety (safe functionalities, functional insufficiencies including cybersecurity) of the driving system must be guaranteed. Therefore, a generic Safety Management System (SMS), that includes all useful and necessary regulations should be applied. The given specifications regarding the safety of driving systems shall be understood and considered in order to define an acceptable SMS for the Highly Automated Driving Function (HADF). Derived from the generic SMS a specific management system has to be developed to guide the development and deployment of the HADF. The research presented in this paper investigates the currently available SMS in different sectors like aviation, marine, and railway to propose a new set of components and elements that are useful and modified for a HADF's SMS. Moreover, the paper provides a systematic approach to how the new set of components and elements can be applied for a HADF SMS. Additionally, well established hazard identification methods (scenario-based HARA and STPA) are compared and integrated into the safety concept phase. The complexity of scenarios is unique for a HADF. Since the SMS is going to be complicated for automotive HADFs and a constantly developing process, methods for evaluation and continuous improvement are needed. This paper gives insight into the structure of the SMS and to guarantee its applicability the use of a helpful software tool is considered. Furthermore, the proposed SMS approach can be adjusted as a groundwork for research concerns like validation for homologation and assess the safety of a HADF.
R032 **16:10-16:25**	Quantification of preconditions for processing safety relevant vehicle systems Hassan Noun, Christian Urban-Seelmann, Mohamed Abdelfattah, Dr. Rajesh G, Dr. Iryna Mozgova, Prof. Dr.-Ing Roland Lachmayer Presenter: Hassan Noun, ZF CVCS, Germany

	Abstract: The international standard ISO 26262 is used to derive new development processes, work products and roles during product development in the automotive industry. For a suitable development of safety relevant vehicle systems, the new work steps must be integrated into the existing development process. The challenge is to apply a proper method for an integration of these additional activities. For the integration a quantification of the process maturity of the safety relevant development processes supports thereby, in order to make a statement about the precondition for the treatment of safety relevant vehicle systems. Furthermore, this identifies development fields in the process integration. This paper shows how a coefficient for measuring process maturity is established. Therefore, the functional safety related activities are identified and isolated. In the next step supporting processes are defined. Further, weighted means are determined. The aim is to have an indicator for the safety relevant development processes already at the beginning of the development and thus to be able to take appropriate measures in advance. As an application example, a project in the automotive sector for an electronic air suspension system is considered. This is followed by differentiated derivations of measures based on the established coefficients for the individual domains.
R038 **16:25-16:40**	Discovery of Perception Performance Limiting Triggering Conditions in Automated Driving Ahmad Adee, Roman Gansch, Peter Liggesmeyer, Claudius Glaeser and Florian Drews Presenter: Ahmad Adee, Robert Bosch GmBH, Germany Abstract: Highly automated driving (HAD) vehicles are complex systems operating in an open context. Performance limitations originating from sensing and understanding the open context under triggering conditions may result in unsafe behavior, thus, need to be identified and modeled. This aspect of safety is also discussed in standardization activities such as ISO 21448, safety of the intended functionality (SOTIF). Although SOTIF provides a non-exhaustive list of scenario factors to identify and analyze performance limitations under triggering conditions, no concrete methodology is yet provided to identify novel triggering conditions.

	We propose a methodology to identify and model novel triggering conditions in a scene in order to assess SOTIF using Bayesian network (BN) and p-value hypothesis testing. The experts provide the initial BN structure and conditional belief tables (CBTs) that are learned using dataset. P-value hypothesis testing is used to identify the relevant subset of scenes. These scenes are then analyzed by experts who provide potential triggering conditions present in the scenes. The novel triggering conditions are modeled in the BN and retested. As a case study, we provide p-value hypothesis testing of BN of LIDAR using real world data.
R046 **16:40-16:55**	Automated Method for Assurance Case Construction from System Design Models Charles Hartsell, Nag Mahadevan, Abhishek Dubey, Gabor Karsai Presenter: Charles Hartsell, Vanderbilt University, USA Abstract: Many Cyber Physical Systems (CPSs) operate in safety- or mission-critical applications where strong assurance of safe operation is required. Assurance cases are one widely used tool for presenting an argument in support of system safety requirements backed by a body of evidence - e.g., test data, formal analysis, or expert review. A system assurance case should regularly evolve during the development process as the system design is refined, but construction and refinement of the assurance argument is a labor-intensive and error-prone process. Reuse of common patterns from successful arguments is one prominent technique for reducing the required effort, but instantiation of these patterns still requires manual compilation and organization of the relevant information from system artifacts. Since model-based engineering techniques are common for CPS development, the relevant information is often contained in a set of interconnected models describing the system. In this paper, we present a method for assurance case construction based on the instantiation and composition of patterns. This method automates the collection and organization of necessary information by extracting it directly from an existing set of system design models. To support human review and refinement, the generated assurance case maintains (1) traceability from objects in the argument back to the corresponding system models and (2) explainability of choices made during the construction process based on the relationships between model objects.

R042 **16:55-17:10**	IEC 61508 and ISO 26262 – A Comparison study Abdellatif Nouri, Jens Warmuth Presenter: Abdellatif Nouri, Fraunhofer Institute for Integrated Circuits IIS, Division Engineering of Adaptive Systems EAS, Germany Abstract: In the process of realizing safety critical systems, guaranteeing functional safety is always mandatory. However, multiple factors are challenging functional safety: (i) the complexity of new electrical and electronic architecture leading to different malfunctioning behavior. This malfunctioning behavior can lead to unwanted hazards and then to unreasonable risk, (ii) the availability of various functional safety standards and (iii) high expenses. If functional safety standards are used in the design of a safety critical system, it is important to evaluate the risk accurately. The risk is related to the probability of failure. In this paper, a comparison between two functional safety standards ISO 26262 and IEC 61508 is presented. These standards are used in the automotive field and in the industrial automation field, respectively. Additionally, a limitation in using IEC 61508 to verify ISO 26262 is emphasized. Focus is the safety lifecycle and the failure rate evaluation methods, which are applied by the two standards. The comparison made in this paper represents the opinion of the authors based on their experience and is not intended to be absolute.
R061 **17:10-17:25**	Towards Qualitative and Quantitative Dependability Analyses for AR-equipped Socio-technical Systems Soheila Sheikh Bahaei and Barbara Gallina Presenter: Soheila Sheikh Bahaei, Malardalen University, Sweden Abstract: Augmented Reality technologies are becoming essential components in various socio-technical systems. New kinds of risks, however, may emerge if the concertation between AR, other technical components and socio-components is not properly designed. To do that, it is necessary to extend techniques for risk assessment to capture such new risks. This may require the extension of modelling languages and analysis techniques.

	In the literature, modeling languages have been already extended by including specific language constructs for socio aspects in relation to the AR-impact. No satisfying contribution is available regarding analysis techniques. Hence, to contribute to filling the gap, in this paper, we propose an extension of previously existing analysis techniques. Specifically, we build on top of the synergy of qualitative and quantitative dependability analysis techniques and we extend it with the capability of benefiting from AR-related modelled aspects. In addition, we apply our proposed extension to an illustrative example. Finally, we provide discussion and sketch future work.
R066 **17:25-17:40**	Statistical comparison between FMECA improvement methods using inter-rater reliability coefficients Andrés A. Zúñiga, João F.P. Fernandes and Paulo J. Costa Branco Presenter: Andrés Alejandro Zúñiga Rodríguez - IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Portugal Abstract: The comparison between FMECA methods is usually conducted qualitatively by direct comparison between failure modes rankings; nevertheless, this procedure could be impractical for extensive problems. This work introduces the application of the agreement coefficient Gwet's AC2 as an alternative for the statistical comparison between FMECA methods. The agreement assessment do not concern if the rankings are correct, but rather how close the rankings are; in this context, the FMECA methods can be considered as the raters whose ratings will be compared with a reference one using the agreement coefficient. The proposed approach was applied in a blood transfusion case study consisting of eleven failure modes, widely used for FMECA benchmarking; we assessed the agreement between a FMECA reference ranking and five FMECA methods: Fuzzy Vikor, ITHWD, Type-1 and Type-2 Fuzzy Inference Systems and Risk Isosurfaces function. The use of agreement coefficients in the FMECA context proved adequate for the quantitative comparison between the five considered FMECA methods and the reference one, with the Fuzzy-Type method being the one that showed the most agreement regarding the reference one.
R031 **17:40-17:55**	Towards reconciling Safety and Security risk analysis processes in railway remote driving Sadek Rayan Aktouche, Mohamed Sallak, Abdelmadjid Bouabdallah, Walter Schön

	Presenter: Sadek Rayan Aktouche, Université de technologie de Compiègne, France Abstract: Modern control systems, and particularly railway systems are heavily rooted on Safety practices in terms of risk analysis and architecture modelling. Often supported by standards such as CENELEC EN50126. However, railway systems are becoming increasingly interconnected and complex as they incorporate telecommunications and information treatment. These additions have opened these previously isolated systems as they become exposed to potential malevolence. The strategic stakes of railway systems instigate major concerns as attacks can cause substantial impacts on infrastructures and human safety. These new risks fall under the banner of Security and more specifically Cyber-security. Traditionally, Safety and Security have been treated either separately, or as the latter integrated in the former. However, the increasing awareness of mutual impacts requires to come up with joint ways to deal with accidental and malevolent risks that compromise the functioning of trains. In this paper, we provide bases for a combined Safety and Security risk assessment and analysis approach that reconciles risk analysis processes from both Safety and Security by making relevant connections at different stages of the two processes and by adding cross-cutting steps common to Safety and Cybersecurity.

Oral Session 3 – Reliability Analysis and Evaluation - Nov. 26, 9:00-11:25

Session Chair: Francesco Di Maio, Politecnico di Milano, Italy

Venue: Meeting room – Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Session keynote lecture Online **9:00-9:25**	Prescriptive Analytics of Network Resilience: An Optimization-Based View Yiping Fang, Université Paris-Saclay, France Abstract: Prescriptive analytics refers to developing quantitative models for identifying and evaluating a feasible course of actions to best achieve specified objectives. In this talk, we focus on prescriptive analytics for infrastructure network resilience and the role of optimization models for studying it. I hope to provide the audience of ICSRS with an appreciation that a particular optimization model can improve an aspect of network resilience and that selecting an appropriate model is important when one wants to improve network resilience. This will be illustrated by several concrete exemplary studies. The scope of this talk is on the resilience of physical or cyber-physical systems and how networks can be used to study them. However, proposed methodologies and drawn conclusions may inform broad applications and systems. Finally, I outline some of the most promising and important directions for continued research and contribution
R037 **9:25-9:40**	A Modeling Framework for the Analysis of Integrated Energy Systems exposed to NaTech Events induced by Climate Change F. Di Maio, P. Tonicello, E. Zop Presenter: Prof. Francesco Di Maio, Politecnico di Milano, Italy Abstract: This paper proposes a modeling framework for the analysis of Integrated Energy Systems (IESs) that comprise nuclear, conventional and renewable power plants, and the electricity infrastructure. With such framework, standard Centralized Systems

	(CS), IES with Distributed Generation (IES-DG) and IES with bidirectional energy conversion (IES+P2G) enabled by power-to-gas (P2G) facilities can be analyzed by innovatively considering the effects of both climate-induced and stochastic failures on their performance. The developed analysis framework has been applied to a typical case study of an IES+P2G that comprises two Combined Cycle Gas Turbine Plants (CCGT), a Nuclear Power Plant (NPP), two Wind Farms (WF), a Solar Photovoltaics (PV) field and a Power-to-Gas station (P2G).
R044 **9:40-9:55**	Co-Simulation and Discrete Event Simulation for Reliability Assessment of Power System and ICT: A Comparison Michele Garau, Romina Muka, Poul E. Heegaard and Bjarne E. Helvik Presenter: Michele Garau, SINTEF Energy Research, Norway Abstract: Modern power systems are increasingly relying on Information and Communication Technologies (ICT) to support their operation. This digitalization process introduces new complexity, which requires novel methodologies to assess the reliability of power systems. Currently, co-simulation and Discrete Event Simulation (DES) are the most popular approaches to analyse the complexity of power grids seen as cyber-physical systems, and to help decision makers in identifying potential sources of failures and implement mitigation actions. This paper compares these two methods. Co-simulation and DES approaches are applied to a power system voltage regulation case study, and the capability of the methods to assess unsolved overvoltages due to simultaneous failures of power system and ICT system is comparatively discussed. Simulation time and assessment of voltage regulation operational costs for both methods are also compared. The paper's main goal is to provide guidance to researchers in evaluating and developing the most suitable simulation approaches for reliability studies in cyber-physical power systems.
R084 **9:55-10:10**	Fusion of Data and Expert Knowledge for Fault Tree Reliability Parisa Niloofar, Sanja Lazarova-Molnar Presenter: Parisa Niloofar, University of Southern Denmark, Denmark

	Abstract: Reliability analysis of cyber-physical systems have benefitted substantially from the introduction of a range of technology enablers. Internet of things (IoT), advanced computing architectures and digital platforms are among the new technologies that are enhancing the data collection and analytics perceptions in the era of Industrial 4.0. Fault tree modelling and failure analysis of systems have been traditionally performed using exhaustively expert knowledge. However, nowadays cyber-physical systems are equipped with sensors and meters, enabling reliability analysis to become more automated and less human-dependent. There have been approaches that fully depend on data that utilized these new developments. However, completely ignoring human cognitive capabilities and expert knowledge causes a great loss of information, which might only be compensated by collecting a large amount of data that is costly in many aspects, and sometimes even impossible. In this paper we discuss how and to what extend expert knowledge can be fused or combined with data to learn fault trees of cyber-physical systems. We, furthermore, point out the gap in availability of systematic methods for fusing data with expert knowledge for the purpose of reliability analysis of cyber-physical systems. Results of a simulation study indicate that hybrid reliability analysis of a system increases the accuracy and is less tedious.
R090 **10:10-10:25**	Dynamic Reliability Assessment of Cyber-Physical Energy Systems (CPEs) by GTST-MLD Zhaojun Hao, Francesco Di Maio, Enrico Zio Presenter: Zhaojun Hao, Politecnico di Milano, Italy Abstract: Cyber-Physical Energy systems (CPEs) are highly connected and remotely controlled systems for energy production, transmission and distribution. Failures of CPEs can occur in both their cyber and physical parts and may, in both cases, result in significant economic losses, service interruption and, even threats to the environment and the population. Traditionally, safety and security of CPEs are addressed separately, the former dealing with failures in the physical part, the latter with breaches in the cyber part. While physical aging is often accounted for, it is not for the cyber elements although it may have an impact on CPEs

	controllability, stability and, ultimately, reliability. In this paper, we propose a dynamic reliability assessment framework that embeds a multi-state cyber aging model of literature into a Goal Tree Success Tree-Master Logic Diagram (GTST-MLD) that accounts for both stochastic hardware components failures and cyber aging that may open breaches for cyber attacks to the control system. The digital Instrumentation and Control (I&C) system of the Advanced Lead-cooled Fast Reactor European Demonstrator (ALFRED) is considered as an example to show the applicability of the GTST-MLD based dynamic reliability assessment method proposed.
R034 **10:25-10:40**	A short review on the integration of Expert Knowledge in prognostics for PHM in industrial applications Antonin Gay, Benoit Iung, Alexandre Voisin, Phuc Do, Rémi Bonidal and Ahmed Khelassi Presenter: Antonin Gay, Université de Lorraine, France Abstract: Optimizing maintenance is essential for industrials to stay competitive, and the development of appropriate predictive maintenance is necessary to achieve this objective. To this extent, the Prognostics and Health Management (PHM) paradigm is well established. One of the key steps of PHM is the prognostics of health states of the system. Various state-of-the-art approaches exist for prognostics, with an emerging orientation towards data-driven methods. Indeed, they have lot of potential for Industry 4.0 applications with high amount of data from sensors and control equipment. However, labelled data (i.e., failures of systems) is not always available on real-life applications where preventive maintenance is often already applied. Thus, the learning databases can be unbalanced, with few learning examples, consequently reducing the learning capacities of algorithms, as well as their generalization. One way to optimize learning on such applications is then to use Expert Knowledge, which can provide additional information on the system and its operating model. A challenging issue is herein the development of a general methodology to integrate the Expert Knowledge into data-driven methods. To face this challenge, this paper aims to propose a categorization of Expert Knowledge based on existing works to identify adapted methods that can help to integrate efficiently the available Knowledge into relevant prognostics algorithms. The

	proposed categorization will allow and facilitate the review and comparison of approaches and methodologies introduced in the literature and in further research. Finally, the proposed classification will be illustrated on a real case of prognostics for a hydraulic circuit from an ArcelorMittal plant.
R095-A **10:40-10:55**	Operation and Maintenance Optimization of Grid-connected Microgrids Using Deep Reinforcement Learning Luca Pinciroli, Piero Baraldi, Michele Compare, Enrico Zio Presenter: Luca Pinciroli, Politecnico di Milano, Italy Abstract: The renewable energy industry is at the center of the energy transition, because of the opportunities it offers for dealing with the expected energy demand increment and climate change, and the requirements of sustainable development. This has led to technological advancements in renewable energy exploitation, storage and distribution. One way to implement these advancements onto the existing electricity grid is by means of microgrids, which are energy systems composed by distributed energy generation, local loads and energy storage capacity. The operation of microgrids is challenged by the uncertainty of intermittent energy sources, like the photovoltaic and wind energy ones, the variability of the demand, the stochastic occurrence of unexpected outages of the conventional grid and the degradation of the energy storage, which is strongly influenced by its operating conditions such as the depth of discharge and the number of performed charge-discharge cycles. To smoothly address these challenges, one can define a proper Operation and Maintenance (O&M) management strategy of the Energy Storage System (ESS) to minimize the unmet demand and maximize the profit provided by the electricity exchange with the conventional grid. Even though several works in the literature have already dealt with the problem of microgrid energy management optimization, few works have considered the energy storage system degradation and maintenance issues, and the possible occurrence of unexpected outages of the conventional grid. Furthermore, literature works usually address only the one day-ahead scheduling problem and not the long-time horizon of microgrids operation.

	In this work, we propose a deep reinforcement learning-based approach for the simultaneous optimization of both operation and maintenance of the energy storage system. The approach is tested on a case study in which the loads of a residential building can be satisfied by means of a grid-connected microgrid equipped with photovoltaic modules and an ESS. Strengths and weaknesses of the proposed approach are analyzed by means of a comparison with state-of-the-art O&M policies.
R098-A **10:55-11:10**	A Physics-Informed Autoencoder for Early Fault Detection of Electro-Hydraulic Actuators Chenyang Lai, Piero Baraldi and Enrico Zio Presenter: Chenyang Lai, Politecnico di Milano, Italy Abstract: With the exploded amount of data available in the industry 4.0 era, deep learning-based models for fault detection, diagnostics and prognostics are becoming more and more attractive. However, two main issues are limiting the application of deep learning-based methods to Prognostics and Health Management (PHM) of complex and safety-critical industrial systems: 1) the scarcity of data collected from systems operating with very degraded or faulty components, which is due to the fact that they tend to operate in healthy conditions, and the cost and risk of acquiring data on equipment behaviour in abnormal conditions are typically not acceptable; 2) the possible inconsistency of the outcomes of deep-learning models with the physics laws [1]. Recently, research on Physics-Informed Neural Network (PINN) has been receiving growing attention for integrating data and physics knowledge [2-7]. In this work, we develop a physics-informed deep learning model for fault detection of electro-hydraulic actuators, which are safety-critical components of turbofan engine fuel systems. The problem has been tackled by generating degradation and failure data using a physics-based model of the component behaviour, and by developing an Autoencoder (AE) for reproducing the system behaviour in normal conditions. By so doing, we are able to integrate into the loss function a physics-based relationship among the physical quantities involved. The results on a simulated case study show that the physics-informed AE provides a more satisfactory performance than a traditional autoencoder and pure physical model.

R101-A **11:10-11:25**	A Heterogeneous Transfer Learning Method for the Prediction of the Remaining Useful Life of Industrial Equipment Bingsen Wang, Piero Baraldi, Ahmed Shokry and Enrico Zio Presenter: Bingsen Wang, Politecnico di Milano, Italy Abstract: Deep learning-based methods for Remaining Useful Life (RUL) prediction require: i) availability of historical run-to-failure data for model training; ii) similarity between the distributions of the test data, which the model is applied to, and the training data. However, these two conditions are not met in several industrial applications, where failure data are rare, and operating and environment conditions are changing in time or from one component to another, causing a modification of the data distributions from training to test. These issues are currently addressed by Domain Adaptation (DA) methods, which reduce the divergence between the training and test data distributions by developing domain-invariant features. This work considers the challenging situation in which training and test data are collected in different feature spaces, possibly characterized by different dimensionality. This is common when the training data are collected during run-to-failure experiments in labs, where the component degradation can be directly measured, whereas the test data are acquired during field operation, where degradation cannot be measured given the lack of ad-hoc sensors. This work develops a heterogeneous Transfer Learning (TL) method for RUL prediction. First, the missing information about the degradation of the test component is estimated by learning from the training data the mapping between the measured signals and the degradation indicator. Then, the RUL of the test data can be predicted using the general TL framework to leverage the prognostic knowledge in the labeled training data. The RUL predictions obtained in an artificial case study show the promising performance of the proposed method.

Oral Session 4 – System Security and Evaluation - Nov. 26, 13:30-16:25

Session Chair: Ibrahim Ahmed, Politecnico di Milano, Italy

Venue: Meeting room – Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Session keynote lecture Online 13:30-13:55	Building Bayesian Belief Networks from operational events and expert judgment: a human reliability analysis application Luca Podofillini, Paul Scherrer Institute, Switzerland Abstract: Bayesian Belief Networks (BBN) are receiving increasing attention by the risk analysis community because of their visualization intuitiveness, ability to accommodate multiple types of data, potential to represent multi-layered influences. An important challenge to their development is the quantification of the model underlying relationships, in the form of conditional probability distributions (CPDs). This talk presents on-going work to develop a BBN for human reliability analysis application, based on a database of human failures in nuclear power plants operational events as well as on expert judgment. The operational events and expert judgment are used to derive the CPDs of selected combinations of influencing factors. The missing CPDs are populated via a CPD fill-up method, the functional interpolation method. The BBN response on other operational event cases is used as partial verification of the model.
R007 13:55-14:10	A structured methodology for the Safety Key Performance Indicator prioritization: a case study La Fata Concetta Manuela, Giallanza Antonio, Micale Rosa, La Scalia Giada Presenter: Rosa Micale, Università degli Studi di Palermo, Italy Abstract: Nowadays, companies have become more and more attentive to the management and evaluation of activities, processes

	and actions related to the safety in workplaces. This attention stems from both the need to comply with law requirements and to improve the productivity of the company by ensuring the reduction of occupational injuries and diseases. Accordingly, performance evaluation is a fundamental step also theorized by the most important guidelines on Occupational Health and Safety Management Systems (OHSMSs). With this recognition, the present paper provides a methodology to prioritize Safety Key Performance Indicators (SKPIs) starting from an initial set selected from the literature. Referring to a passengers' transportation company located in the Southern of Italy, the ranking of the most suitable SKPIs to monitor the effectiveness of measures taken by the company to prevent and/or mitigate risks in workplaces is obtained by the Analytic Hierarchy Process (AHP) method.
R045 **14:10-14:25**	Safety and Security Concept for Software Updates on Mixed-criticality Systems Imanol Mugarza, Irune Yarza, Irune Agirre, Fabrizio Lussiana, Stefania Botta Presenter: Imanol Mugarza Inchausti, Ikerlan Technology Research Centre, Spain Abstract: The raising connectivity of critical embedded systems makes them vulnerable to cyber-security attacks that compromise not only privacy but also safety. This results in intricate dependencies between functional safety and security and higher demands to address both disciplines simultaneously. However, there are still many gaps on the common application of functional safety and cyber-security standards. Over-The-Air (OTA) software updates are a clear example of this challenge. While the installation of regular software upgrades is a crucial cyber-security practice to keep the system up-to-date with latest security patches, they might involve high re-certification efforts and costs from a safety standpoint. In this paper, a safety and security concept for software updates on mixed-criticality systems is presented. Particularly, a combined safety and security risk analysis on an automotive use case is performed and risk mitigation measures proposed.
R078 **14:25-14:40**	Development of DRL-based controller for Nuclear Power Plants of Normal and Emergency Operations Daeil Lee, Hyojin Kim, Younhee Choi, Jonghyun Kim Presenter: Daeil Lee, Chosun University, Republic of Korea

	Abstract: Nuclear power plants (NPPs) are highly automated systems. Nevertheless, the operator's manual actions are still required when normal (start-up/shutdown) operation and emergency operation. During these operations, operators execute necessary actions (e.g., situation awareness, confirmation of automatic actuation, and manipulation) following the operating procedures. This study suggests a Deep Reinforcement Learning (DRL)-based autonomous agent. The agent can manage the power increase operation from 2% to 100% and reduce the pressure and temperature until the shutdown cooling entry condition after reactor trip caused by loss of coolant accident in NPPs. The DRL-based controller suggested in this study combines a rule-based system and DRL algorithm that involves a Soft Actor-Critic algorithm and deep neural network. The test results using a compact nuclear simulator indicates that the agent can manipulate components to comply with identified constraints for start-up operation and emergency operation.
R092 **14:40-14:55**	Natural Language Processing and Bayesian Networks for the Analysis of Process Safety Events Dario Valcamonico, Piero Baraldi, Enrico Zio Presenter: Dario Valcamonico, Politecnico di Milano, Italy Abstract: Adequate Process Safety Management System (PSMS) is fundamental to ensure the safety of the operation of process industry assets and prevent the occurrence of Process Safety Events (PSEs), such as unplanned or uncontrolled releases of product. In this work, we consider as source of information a repository of reports of PSEs and we aim at the identification of the factors that influence PSE occurrence and severity. A methodology based on the combination of Term Frequency Inverse Document Frequency (TFIDF) and Normalized Pointwise Mutual Information (NPMI) is developed for the automatic extraction of keywords from PSE reports, and a Bayesian Network (BN) is developed for modeling PSEs consequences.
R094 **14:55-15:10**	Development of Long-Term Prediction Algorithm Based on Component States Using BiLSTM and Attention Mechanism Hyojin Kim, Seungho Jo, Jaehyun Kim, Gayoung Park and Jonghyun Kim

	Presenter: Hyojin Kim, Chosun University, Republic of Korea Abstract: Appropriate situation awareness (SA) of operators is important in managing nuclear power plants (NPPs), especially, in accident situations. Among the three levels of SA suggested by Ensley, Level 3 SA is one of the more difficult tasks due to the complexity of NPP as well as the uncertainty of accidents phenomena. Several prediction models using artificial intelligence techniques have been suggested to help the operator's prediction in the case of accidents. However, those models are capable of predicting the short-term plant status and do not quantify the uncertainty of the prediction. This study suggests an algorithm for predicting the long-term status of plant parameters for 2 hours according to component states and quantifying the uncertainty of the prediction.
R077 **15:10-15:25**	Experimental Analysis of the Effects of Simulator Complexity on Human Performance Taewon Yang, Bumjun Park, Sungheon Lee, Jeong Hun Choi, Jooyoung Park, Ronald L. Boring and Jonghyun Kim Presenter: Taewon Yang, Chosun University, Republic of korea Abstract: Human reliability analysis (HRA), which is used to predict accidents resulting from human errors, is an important factor in probabilistic safety assessments that comprehensively evaluate the safety of nuclear power plants (NPPs). This study analyzes how simulator complexity affects the performance of NPP operators and falls under Idaho National Laboratory's project to collect additional HRA data through the use of simulations. Experiments were conducted featuring two types of simulators and scenarios as independent variables. The data collected via these experiments were further evaluated using an analysis of variance (ANOVA) test and correlation analysis, resulting in the derivation of four human performance charts.
R097-A **15:25-15:40**	An optimization model for determining the optimal set of risk response actions with consideration of risk-related resource-constrained allocation and scheduling Fei Zuo

	Presenter: Fei Zuo, Shenyang Aerospace University; Politecnico di Milano, Italy Abstract: Effective handling of project risks is an important part of project risk management. Numerous of methods have been proposed to determine the optimal set of risk response actions to deal with the project risks. However, these methods ignore the problem of how to allocate and schedule implementation resources for these selected risk response actions. Therefore, this paper aims to propose a risk-related resource-constrained allocation and scheduling method to provide decision supports for project managers. Based on the elaboration of the relationship between risk, risk response action and the risk-related resources, we propose a mix-integer optimization model to obtain the optimal risk response strategy and the project scheduling. To validate the optimization model and investigate the relationship between factors such as risk response efficiency and risk severity, the numerical experiments are conducted. Based on the results show that the project make-span and cost largely affected by the risk severity and the risk response efficiency, and project managers need to determine appropriate risk response strategies based on the corresponding duration and costs to avoid over-response or. This paper aims to integrate project risk management and resource-constrained project scheduling problems. In this way, the method of project risk response can be further improved, and the application scenarios of multi-mode resource-constrained project scheduling problems will be enriched.
R100-A **15:40-15:55**	Development of a Method for Detection of Anomalies in Multi-Stage Production Systems Fatemeh Hosseinpour, Ibrahim Ahmed, Piero Baraldi, Mehdi Behzad, Enrico Zio Presenter: Fatemeh Hosseinpour, Politecnico di Milano, Italy Abstract: We consider a multi-stage production system in which products are manufactured on a lot-basis through several processing steps. This situation is common in several industrial sectors, such as food industry and semiconductor and polymer manufacturing industries [1], [2]. We aim at developing an anomaly detection method that identifies the occurrence of production anomalies in a single stage of the production process on the basis of monitoring signals collected during production [3], [4], [5].

	The main challenges to be addressed are the large number of monitored signals and the lack of labeled data for which it is known whether an anomaly has occurred during the considered production stage. The present work develop various feature extraction and selection techniques for the extraction of relevant features from the multidimensional time series collected from the sensors during production. Also, different unsupervised methods for anomaly detection, like Principal Component Analysis (PCA), Auto Associative Kernel Regression (AAKR) and Autoencoders, are considered [6], [7], [8].
R080-A **15:55-16:10**	An Unsupervised Fault Isolation System for Steam Turbine Condition Monitoring Zhen Chen, Enrico Zio, Ershun Pan Presenter: Zhen Chen, Shanghai Jiao Tong University, China Abstract: Condition monitoring of the steam turbine based on Turbine Supervisory Instrument (TSI) data plays an essential role for power plant health management. Nevertheless, some inherent shortcomings of the TSI data, including a low sampling rate, high dimension and lack of historical fault data, bring many challenges. In addition, due to the external interference and the complicated relationships among the variables relevant to the operation process, the monitoring data is non-stationary, non-Gaussian and noisy. To address these problems, this study proposes an unsupervised fault isolation system for robust steam turbine condition monitoring. Singular spectrum analysis is first used for non-stationary signal decomposition and only approximate stationary components of the signals are retained to represent the in-control and noise-free characteristics of normal conditions. Next, a Gaussian process mixture (GPM) model is developed to dynamically capture the extracted multi-dimension data and provide in output more reliable posterior confidence intervals of normal signals. Based on this, any anomaly in the signals can be detected as a sign of potential faults. For this, we construct a global statistic based on the distance between the incoming monitoring data and posterior intervals. When an anomaly is identified, the faulty variable is isolated by a spare reconstruction strategy without priors. The proposed system can online isolate multiple faulty variables that are responsible for

	the abnormal conditions without any prior information. The effectiveness of the proposed system is demonstrated on a real case of an operating steam turbine.
R089-A **16:10-16:25**	Subset simulation, line sampling or cross entropy: at the end it is always the design point Karl Breitung Presenter: Karl Breitung, TU Munich, Germany Abstract: The FORM/SORM methods determine the design points where the probability density in the failure domain is maximal and make Taylor expansions around them. However, for increasing dimensions the so derived approximations become imprecise. Therefore since twenty years there is a trend to supersede FORM/SORM by other methods which seem to be better suited for high dimensional cases. But the new popular methods nowadays --- subset simulation, line sampling and cross entropy --- all end up by approximating the design point(s) and making approximations around it(them) via some MC methods. This does not appear in the description of these approaches, where the concept of design points is never mentioned. However, with a mathematical analysis of the algorithms it can be demonstrated that in fact they all methods use the design point as center of their MC estimation structure. Therefore, these approaches are inefficient in comparison with methods which start from the design points. Further these methods discard the information which they have gathered about the structure of the failure domain, i.e. the design points; so a major part of the obtained information is thrown away. Starting from asymptotic analysis concepts for improved approximations using design points and MC methods to refine them can be found. This allows to combine the structural information from the design points with MC refinements of the probability estimation.

Online Session C – Fault Diagnosis and Detection - Nov. 26, 9:00-11:40

Session Chair: Sameer Al-Dahidi, German Jordanian University, Jordan

Breakout Room: Zoom Link: https://zoom.us/j/97008300466 Password: 112426

Session keynote lecture Onsite 9:00-9:25	Domain adaptation for intelligent maintenance systems Olga Fink, Professor of Intelligent Maintenance Systems, ETH Zürich Abstract: The amount of measured and collected condition monitoring data for complex infrastructure and industrial assets has been recently increasing significantly due to falling costs, improved technology, and increased reliability of sensors and data transmission. However, faults in safety critical systems are rare. The diversity of the fault types and operating conditions makes it often impossible to extract and learn the fault patterns of all the possible fault types affecting a system. Consequently, faulty conditions cannot be used to learn patterns from. Even collecting a representative dataset with all possible operating conditions can be a challenging task since the systems experience a high variability of operating conditions. Therefore, training samples captured over limited time periods may not be representative for the entire operating profile. The collection of a representative dataset may delay the implementation of data-driven fault detection and isolation systems. The talk will provide insights into potential solutions that enable to transfer models and operational experience between different units and between different operating conditions also in unsupervised setups where data on faulty conditions is not available. Moreover, a synthetic-to-real framework for domain adaptation will be presented, where only knowledge of the healthy class is needed.
R020	Failure Criticality Importance Analysis in the Steady-State Condition Masahiro Hayashi Presenter: Masahiro Hayashi, Tokyo City University, Japan

9:25-9:40	Abstract: We propose to use failure criticality importance in the steady state as a reliability importance measure. While the existing failure criticality importance is an easily understandable and useful measure, its evaluation methods are problematic because they use simulations or Markov reward analysis of finite interval; the simulation method may show unstable results, while the Markov reward analysis is prone to an exponential increase in the number of states even for simple combinatorial models. Why do researchers persist in using a failure criticality importance for finite intervals, while analyses in finite intervals are known to be more difficult than steady-state analyses? Because research on failure criticality importance starts with simulations and simulations must stop within a finite interval for technical reasons, we emphasize that the analytical method would be easier in a steady state, which is commonly assumed in real system. Here, we give a method to evaluate the failure criticality importance in the steady-state condition with high efficiency for the combinatorial model and demonstrate its effectiveness in numerical examples.
R021 9:40-9:55	Failure scenarios of power system protection Soumita Ghosh, Siddhardha Kedarisetty, Debomita Ghosh and Dusmanta Kumar Mohanta Presenter: Soumita Ghosh, Department of Electronics and Communication Engineering, IcfaiTech (Faculty of Science and Technology), IFHE, India. Abstract: The increasing dependency on electrical energy in every aspect of modern times has impelled the need for reliable, resilient, and well-protected power infrastructure. As a matter of fact, power system protection plays a decisive role in defending the power system from damages that might be incurred due to faults by fault identification, isolation, and clearance. Therefore, in this work, we analyze the power system protection for a transmission line equipped with a PMU-based auto-recloser. For analysis, we have chosen Petri nets since they

	efficiently demonstrate the dynamic behavior of real-world systems. This PN model is used to exemplify the qualitative performance measures of the protection system model through behavioral properties such as conservativeness, reachability, properness, safeness, and boundedness. Thereafter, we extend the PN model developed for an ideal transmission line protection system to derive failure scenarios in the protection system that result due to three of its important components: relay, circuit breaker, and auto-recloser device. A systematic study of failure scenarios related to the aforementioned components is mandatory to decipher their effect on the functionality of power system protection. Relay failures are categorized as hardware and software failures; the effect of the stuck circuit breaker is analyzed, and PMU-based auto-recloser is studied for hardware, software, and PMU-failures. The failure analysis is necessary for yielding appropriate solutions to failures, improving system design, introducing a new device to aid the system functionality, and aiding the recovery process, which eventually leads to a more reliable system. Therefore the sole aim of this paper is to provide accurate modeling for the failures to alleviate the process of power system protection.
R033 **9:55-10:10**	Dependency-aware Fault Tree Analysis Alexander Prohaska Presenter: Alexander Prohaska, AUDI AG, Germany Abstract: The proposed method enables fault tree analysis (FTA) to handle specific dependencies between basic events innately. The supported dependencies are mutually exclusiveness, negation, implication and influencing dependency. Dependent events have unique event labels which are traced throughout the fault tree. Depending on the set of traced events included in a gate, several conditional probabilities are calculated to measure the influence of single events or event groups at that gate. Logical modeling errors, like the presence of two mutually exclusive events, are recognized and the occurrences of dependent and repeated events are taken into account during probability calculation. This also includes negated events, making the approach

	suitable for non-coherent FTA. In dependency-aware fault tree analysis (DaFTA), standard fault tree gates are calculated by splitting the solution space into several sub-results which are calculated using the conditional probabilities of including and excluding selections of labeled events. For a moderate fraction of traced events, DaFTA leads to a significantly lower number of terms during inclusion-exclusion calculation, compared to precise minimal cut set analysis, without losing precision. Optionally, any basic event of interest can be selected for tracing, making it possible to perform impact analyses for single events or event combinations.
R057 **10:10-10:25**	Fault Detection for Automatic Guided Vehicles Based on DecisionTree and LSTM Xiaohu Ding, Dongdong Zhang, Liangang Zhang, Lei Zhang, Changjiang Zhang, Bin Xu Presenter: Xiaohu Ding, Tongji University, China Abstract: Automatic Guided Vehicle (AGV) is one of the most important automation equipment in Automated Container Terminal (ACT). The normal operation of AGV equipment plays a vital role in maintaining highly efficient operation of ACT. In this paper, we propose an AGV equipment fault detection algorithm that combines the advantages of traditional machine learning in rule learning and deep learning in hidden layer feature extraction. Our algorithm distinguishes uncertain state data with the help of Long Short-Term Memory (LSTM) networks based on pre-classification of targets using decision tree models, which can both improve the fault detection accuracy and reduce the complexity of network training. In addition, we use a real dataset from automatic guided vehicles at Qingdao port container terminals to evaluate the effectiveness of the algorithm. The experimental results show that our algorithm outperforms a single decision tree model and an LSTM model in terms of classification performance, and can achieve 98.9% accuracy.
R081 **10:25-10:40**	Classifying Fault Category and Severity of UAV Flight Controllers' Reported Issues Anamta Khan, Maria Lucia Ferramosca, Naghmeh Ivaki and Henrique Madeira Presenter: Anamta Khan, Centre for Informatics and Systems of the University of Coimbra, Portugal

	Abstract: Unmanned Ariel Vehicles (UAVs) have gained significant importance in diverse sectors. Thus, a profound safety risk analysis/assessment to prevent any possible damage to themselves, the environment, and humans is fundamental for building and utilizing UAVs. To achieve that, two fundamental challenges should be addressed: i) identification of types and frequency of the issues and ii) assessment of their impact. In this paper, we aim to address the first challenge by automatizing the process of data field analysis. To do so, we first performed some statistical analysis of the reported issues of UAV systems (in Github) and manually extracted detailed data from the reports to better understand the type and nature of the issues. Then, to automatize the analysis, we used natural language processing algorithm to extract the \textit{keywords} from the reports, and then applied four machine learning algorithms to build classifier models to classify the reports according to the fault category and severity level. The good performance results obtained suggest that these analyzes can be performed to further understand the UAV system issues, and help in the risk assessment procedure to identify the hazard and define the frequency and severity of the risk. Moreover, the results of this work can help a big community of developers and researchers in the precise and fast analysis of bug reports and safety risk assessment of any software system.
R088 **10:40-10:55**	Adaptive Semi-supervise Graph Neural Network for Fault Diagnosis of Tunnel Ventilation Systems Hao Chen, Xian-Bo Wang and Zhi-Xin Yang Presenter: HAO CHEN, University of Macau, China Abstract: Tunnel fans are typical and key fire-fighting electromechanical equipment to ensure the ventilation and safety of tunnel traffic. Effective maintenance of such a group of complex electromechanical equipment servicing in hazard environment is challenging for vulnerable to unexpected failure. However, the widely applied deep learning methods lack the capability that extracting features from sample organization. A novel semi-supervised graph neural network (ASGNN) is proposed that is adaptive to fluctuate fault features. First, a clustering method is proposed to develop a knowledge alignment layer for the

	construction of the graph. Then, the embedded representation of the graph network is introduced to aggregate the information of the whole graph. Finally, an expectation-maximization (EM) algorithm-based learning method is developed to realize the alternate learning of both signal and relationship features. The proposed fault diagnosis solution has been verified with experiments, and the results demonstrated that the proposed method outperformed the state-of-the-art solutions.
R091 **10:55-11:10**	CFD-based Heat Dissipation Efficiency Monitoring for Radiator in Different Air-cooling Modes Lujia Wang, Wanwan Zuo, Zhi-Xin Yang, Zhenlu Cai, Peixi Ma and Ziheng Ye Presenter: Lujia Wang, University of Macau, China Abstract: In order to achieve accurate temperature monitoring and status detection of the transformer cooling radiator, the safe and efficient operation of the oil-immersed transformer cooling system is further realized. In this paper, the radiator of an oil-immersed transformer is the research object. Based on heat transfer, fluid mechanics, and energy conservation, the three-dimensional numerical model of the oil-natural air-natural (ONAN) and oil-natural air-forced (ONAF) cooling modes are established respectively. The CFD simulation verifies the validity of the model and analyses the heat dissipation of the radiator, and the oil exponent of the thermal parameters of the transformer is revised. In addition, the characteristics of the temperature rise of the radiator before and after the failure of the transformer cooling fan are also studied in this paper. In the process of the temperature rise of the radiator, the local area of the excessively high oil temperature is located, which provides a reference for the maintenance and efficiency improvement of the transformer cooling system.
R058 **11:10-11:25**	Knowledge based training derived from risk evaluation concerning Failure Mode, Effects and Criticality Analysis in autonomous railway systems Clemens Gnauer, Andrea Prochazka, Elke Szalai, Sebastian Chlup, Sabrina Luimpöck, Anton Fraunschiel and Christoph Schmittner Presenter: Elke Szalai, Fachhochschule Burgenland GmbH, Austria

	Abstract: When building digital solutions security and safety are essential, especially in critical industrial applications. Considering this in connection with people who operate them, we investigate here how such an extension can be applied by using the FMECA analysis. We derived a meta-model for an autonomous railway system. This meta-model includes all relevant components to apply an FMECA assessment including adequate technical and social requirements as well as the assessment of measures for a safety process from the design phase. Before working out the social aspects in the FMECA, methods from Design Thinking were used to combine them with the technical aspects in a structured way. Methods used in Design Thinking processes help to create ideas and to prototype new (technical) products with general know-how about user aspects. This research combines market research, technical development and societal aspects. Assessing safety aspects at the interface between humans and machines, we applied the Persona-Model and developed it further to consider the users' diversity categories and aspects of organizational learning within an industrial unit. The result provides answers to questions about the avoidance of errors, discussions on safety aspects and an outlook on tools that can be used to prevent accidents, such as organizational development tools and knowledge based training materials. At the same time, they offer starting points for creating trust in digital solutions and cyber security for employees.
R048-A **11:25-11:40**	Evaluating and Reducing Aircraft Technical Delays & Cancellations Impact on Reliability Operational: Case Study of Airline Operator Adel Ghobbar and Ahmad Bakkar Presenter: Adel Ghobbar, SORT Engineering Services GmbH, Germany Abstract: Although special care is given to maintenance, aircraft systems fail and these failures cause delays and cancellations. The occurrence of Delays and Cancellations affects operators and manufacturers negatively. Therefore, the reliability team at Fokker

	Services carries out regular meetings with their operators to advise them on Fokker latest findings in this field. As an aircraft manufacturer committed to servicing their customers, a part of Fokker Services' mission is to improve reliability. This is done by reducing technical delays and cancellations. To reduce technical delays and cancellations one should be able to determine the important systems causing them, evaluate it and take measures to deal with it. The goal of this research is to find a method to define the most expensive delays and cancellations systems for Fokker operators and to make, if possible, a predictive model that forecasts them and their impact. This was done, first, by carrying out a research that identifies relevant information to tackle the problems faced while answering the questions of this report. Following that, data was obtained from Fokker Services reliability Team database. It was collected for many operators of the F50, F70 and F100 aircrafts. The following operators; KLM, AUA (Austrian Airlines), PGA (Portugalia Airlines) and Cityjet VLM, participated actively to this research by providing information and data. Subsequently delays and cancellations evaluation methods were identified. No cost estimation methods were used due to their complexity. The method developed is new. It takes into account the frequency of delays and cancellations and uses weighting factors to give an indication on the severity of their duration. These weighting factors are from the invoice of the participating operators. A computer software that computes the reliability indicator and the top systems responsible of delays and cancellations was also developed. The goal of this software is to implement it at Fokker Services. In the end, a statistical analysis was performed to determine the parameters that have a significant impact on Delays and Cancellations. Based on this analysis, no predictive model was produced. However, many interesting findings were revealed. Based upon these findings Fokker Services started providing their operators feedback supported with scientific proves on their operation.

Online Session D – Computer and Information Security - Nov. 26, 13:30-15:45

Session Chair: Ewa Dąbrowska, Gdynia Maritime University, Poland

Breakout Room: Zoom Link: https://zoom.us/j/97008300466 Password: 112426

R065 **13:30-13:45**	Conception of Oil Spill Trajectory Modelling: Karlskrona Seaport Area as an Investigative Example Ewa Dąbrowska Presenter: Ewa Dąbrowska, Gdynia Maritime University, Poland Abstract: A theoretical background of process of changing hydro-meteorological conditions impact on oil spill trajectory is presented. A probabilistic procedure to oil spill domain movement modelling is proposed considering the impact of hydro-meteorological factors. The procedure is practically applied to prediction of oil spill domain movement at Karlskrona seaport water area.
R023 **13:45-14:00**	Arithmetic Coding for Floating-Points and Elementary Mathematical Functions Marc Fischer, Oliver Riedel, Armin Lechler Presenter: Marc Fischer, University of Stuttgart, Germany Abstract: Software-based fault tolerance enables the usage of standard hardware in safety-critical applications. Arithmetic coding is a promising approach for fault tolerance and is already used in the area of production systems. To enable the usage of complex safety functions, e.g. in human-robot collaboration, basic mathematical functions must be supported by the software-based fault-tolerance approach. Thereby, the basic mathematical functions require the full support of floating points. Therefore, in this paper, we present a methodology to apply arithmetic coding on all types of floating-point functions including the basic mathematical functions. For each type, an example of implementation is shown. To validate our approach, we use the

	inverse kinematic of a cable robot as an example algorithm where the application of arithmetic coding is done automatically with a source-to-source transformation approach. Fault injection experiments validate the effectiveness of the presented approach.
R025 **14:00-14:15**	Automated 3D Object Reference Generation for the Evaluation of Autonomous Vehicle Perception Robin Philipp, Zhijing Zhu, Julian Fuchs, Lukas Hartjen, Fabian Schuldt and Falk Howar Presenter: Robin Philipp, Volkswagen AG, Robin Philipp Abstract: Understanding the surrounding traffic is a challenging task for automated driving systems. A reliable perception is not only mandatory for safe prediction, planning and subsequent operation in traffic but also serves as a basis for post-analysis to identify and collect encountered scenarios. Evaluating a perception component relies mostly on comparing object hypotheses to a reference. These references are often the result of manual labeling processes which are time-consuming, expensive and can be prone to errors. In this work, we propose a process for the automatic generation of dimension and classification references of perceived objects. Our approach post-processes perceived objects under consideration of sensor mounting information and infrastructure elements defined by an HD map. The dimension reference generation considers reliable measurements that correspond to situations that are assessed as favorable for perceiving the analyzed object. The classification reference is generated by investigating objects towards patterns like specific movement profiles or interactions with infrastructure elements. We show process feasibility and evaluate initial results by comparison with manually labelled object classifications and dimensions based on corresponding camera images. The results show an improved correctness up to 93.7 % regarding object classifications and accuracy of vehicle length and width (RMSE ={37.51 cm, 24.14 cm} respectively). Finally, we discuss how the proposed approach can facilitate perception evaluation.

R026 **14:15-14:30**	Cost Analysis for Two Dimensional Warranted Products Protectedby Lemon Laws Considering Multi Component System Hennie Husniah, Rachmawati Wangsaputra, Udjianna S. Pasaribu and Bermawi P. Iskandar Presenter: Hennie Husniah, Langlangbuanan University, Indonesia Abstract: We study a warranty cost analysis for a product sold with a two-dimensional warranty. During the warranty, the product is also protected by lemon laws for a period which is less than or equal to the warranty period. The product is considered as a multi-component system consisting of two types of components – i.e., critical and non-critical components. Failure of either a critical component or a non-critical component can cause the product to fail. The lemon laws protect the consumer from recurrent failures. In this, we consider that the product turns to be a lemon only due to the number of failures is equal to or greater than the 51hresholdd, (e.g., k). This happens either the number of critical or non-critical component failures reaches k in the lemon law period. The failed product under warranty is always fixed by a minimal repair. We obtain the expected warranty cost and the optimal lemon law period minimizing the expected warranty cost rate. Numerical examples are provided to illustrate the expected warranty cost and the optimal lemon law period.
R027 **14:30-14:45**	Data Augmentation for Vibration Signals using System Identification Techniques Amanda Lucatto Marra, Rodrigo Juliani, Claudio Garcia Presenter: Amanda Lucatto Marra, Escola Politécnica da Universidade de São Paulo, Brazil Abstract: Fault diagnosis of rotating machines by neural networks can be compromised in cases of imbalanced datasets, a common situation in the industry, where it might be necessary to create new data artificially. This subject, called data augmentation, is very recent and, for vibration signals, two approaches are found in the literature: the utilization of signal processing techniques in the time domain, and the creation of signal models by General Adversarial Network (GAN) from the existing signals. However, for this last one, many signal samples are necessary, which may prevent its use for this end. As an

	alternative, it is proposed a new vibration signal modelling method by using System Identification techniques at the frequency domain, where the trigger signal is used as model input and the vibration signal as output. By how it was structured, this method is only applicable in situations where only harmonic signal components are relevant to the diagnostics, case of many practical situations. For a first attempt of vibration signal modelling by System Identification, the results were very satisfactory, since the model responded with similarity to the collected signals in the frequency band of interest to the application. This work opens a new data augmentation research possibility for vibration signals of rotating machinery, a very relevant area and still little explored in the literature.
R055 **14:45-15:00**	Correlating intrinsic parameters and sharpness for condition monitoring of automotive imaging sensors Marcel Kettelgerdes, Lena Böhm, Gordon Elger Presenter: Marcel Kettelgerdes, University of Applied Sciences Ingolstadt, Germany Abstract: With the recent transformation of the automotive industry towards electrified and partially automated driving, the responsibility for reliable environmental perception moves from the driver to the vehicles advanced driving assistance systems (ADAS). As a consequence, the respective sensor systems are becoming more and more safety critical, as well as a major cost driver in modern vehicles. A large portion of automotive sensors consist of imaging devices like mono and stereo cameras for object detection, as well as currently emerging, non-scanning solid-state LiDAR (Light Detection And Ranging) sensors. Within this work, we investigate key parameters to monitor the thermo-mechanical state of the sensor optics and its impact on imaging quality during vehicle operation. Therefore, the intrinsic calibration parameters and modulated transfer function of a commercial, indirect time-of-flight camera were measured under varying operating temperatures in order to uncover major correlations. By doing so, it could be shown that thermally induced deformations within the optical path and the corresponding loss of sharpness can – to a certain extend – be predicted by accurate camera calibration. Hence, this work aims to motivate precise in-field camera re-calibration to continuously monitor the sensors optical system condition.

R062 **15:00-15:15**	Machine Learning based Anomaly Detection of Log Files using Ensemble Learning and Self-Attention Markus Fält, Stefan Forsström, Tingting Zhang Presenter: John Markus Fält, IST Mid Sweden University, Sweden Abstract: Modern enterprise IT systems generate large amounts of log data to record system state, potential errors, and performance metrics. Manual analysis of log data is becoming more difficult as these systems become more complex. Therefore, machine learning based anomaly detection of system logs is a vital component for the future of system management. Existing log anomaly detection models commonly rely on learning the general normal behavior of the target systems to accurately detect anomalies. They are however limited by the often sparse existing system knowledge. Therefore, this paper proposes a general anomaly detection method which requires little or no knowledge of the target system. This is done by assuming there are semantic similarities in different systems' log data. Labeled log data from other systems can then be used for training the anomaly detection model. The model uses self-attention transformers and ensemble learning techniques to learn the semantic representation of normal and abnormal log messages. The proposed method achieves a performance comparable to other log anomaly detection methods while requiring little knowledge of the target system.
R068-A **15:15-15:30**	Improving Aircraft Maintainability and Supportability Performance for Wide-Body A-Checks Delays Adel Ghobbar Presenter: Adel Ghobbar, SORT Engineering Services GmbH, Germany Abstract: Martinair experienced extensive changes in the last 14 years while becoming a subsidiary of KLM and therefore becoming part of the Air France – KLM Group. The Martinair's McDonnell Douglas MD-11 A-check fleet maintenance will therefore be performed by KLM E&M in the near future. Both companies currently experience delays during the performance

	of A-checks. The transfer of the A-check provides a good environment to improve the on-time performance by comparing the companies performing the A-check and search for improvements. The approach of this research is to identify the root causes of the delays for the MD-11 fleet and related them to the company processes within the maintenance departments. The goal is to develop a method to find the most pressing technical A- check delays and to reduce or prevent these delays for the MD-11 fleet and improve the on-time performance of an MD-11 A-check. To reach this goal the processes within the KLM Engineering & Maintenance and Martinair Maintenance and Engineering department are studied. The processes are studied and observed on an organization and department level. This includes internal processes, work packages, communication and ICT resources. Next to the processes, the A-check delay data was collected for the KLM and Martinair operation. The delay data was categorized using the delay reasons and the root causes for the delays had to be identified through research into the processes and operations. An evaluation method for the technical delays was developed. The method takes reliability, delay occurrences and average delay length into account. The most pressing ATA chapter delay occurrences of an A-check are identified using this method. A recommended approach or process for the transfer was constructed for the non-technical delays and the most interesting technical delay cases. These recommended approaches and processes can improve the on-time performance of an A-check significantly by reducing or preventing delays.
R024 **15:30-15:45**	Fault Injecting Co-simulations for Safety Mirgita Frasheri, Casper Thule, Hugo Daniel Macedo, Kenneth Lausdahl, Peter Gorm Larsen, and Lukas Esterle Presenter: Mirgita Frasheri, Aarhus University, Denmark Abstract: Robotic systems, either operating alone or in fleets, in order to be trusted, have to provide certain safety guarantees to ensure no harm comes to neither humans, environment, other robots or equipment. Co-simulation tools enable the integration of models from different modelling applications and can be adopted to ensure the safe behaviour of such systems using simulation.

	Different parameters of the included models can be explored, including safety aspects, by simulating different sets of scenarios. Of particular interest are those scenarios in which different system components fail at different times, potentially leading to safety violations. The core contribution of this paper is a simple but powerful fault injection mechanism, that enables developers to seamlessly inject faults in their co-simulations. We present an initial evaluation of the proposed mechanism through a water-tank case-study, to discuss its applicability and benefits for system evaluation during the development stage. Thereafter, we discuss the value of this work in the context of autonomous agricultural robot fleets, and outline our next steps in this direction.