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Important Announcement

The safety and well-being of all conference participants is our priority. IEEE has been monitoring the developing COVID-19 pandemic (Coronavirus).

The World Health Organization has declared COVID-19 (Coronavirus) to be a pandemic, many governments have enacted travel bans and numerous state and local governments are prohibiting large or even moderately-sized public gatherings. Such bans on travel and public gatherings are likely to increase in number and scope in the coming weeks.

After studying and evaluating the announcements, guidance, and news released by relevant national departments, we are sorry to announce that the in-person gathering of IEEE SYSCON 2022, scheduled to be held April 24-28, 2022 in Montreal, Canada has been cancelled. IEEE SYSCON 2022 will now be held as a virtual conference, to be held April 24 – May 23, 2022. Attendees will receive access to all of the presentations for the duration of the conference! Please stay tuned for more important conference information.

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Keynote

Dinesh Verma, Ph.D., *Stevens Institute of Technology, USA*
"SERC and Its Major Contributions"

Tutorials

Closed Systems Paradigm for Intelligent Systems

Niloofar Shadab and Tyler Cody (Virginia Tech, USA); Alejandro Salado (The University of Arizona, USA); Peter Beling (University of Virginia, USA)

Intelligent systems ought to be distinguished as a special type of system. While some adopt this view informally, in practice, systems engineering methods for intelligent systems are still centered around traditional systems engineering notions of engineering by aggregation and decomposition of components. We posit that this traditional approach follows from holding a notion of open systems as the fundamental precept and that engineering intelligent systems, in contrast, requires an approach that holds notions of closed systems as fundamental precepts. We take a systems theoretic approach to defining open and closed system phenomena and their relation to engineering intelligence. We aim to institute a closed-system approach to characterize intelligence as a property of the system's relation to its context by emboldening the shift from the concepts behind the requirement-functions relationships in systems engineering and aligning them with the presented closed systems view. We propose the concept of variety; particularly the law of requisite variety to enable a closed view paradigm in engineering intelligent systems. We discuss how open and closed view approaches to engineering intelligent systems address variety differently, as well as the implications of this difference on engineering practices. Then, we provide a research roadmap for systems engineers to align their practices with the closed system view.

Multilayer network modeling and stability analysis of Internet of battlefield things

Haihao Ding (National University of Defense Technology, China); Qingsong Zhao (National University of Defense Technology & College of Information System and Management, China)

Intelligent service network under the paradigm of the Internet of Things (IoT) uses sensor and network communication technology to realize the interconnection of everything and real-time communication between devices. Under the background of combat, all kinds of sensor devices and equipment units need to be highly networked to realize interconnection and information sharing, which makes the IoT technology hopeful to be applied in the battlefield to interconnect these entities to form the Internet of Battlefield Things (IoBT). This paper analyzes the related concepts of IoBT, and constructs the IoBT multilayer dependency network model, then constructs the weighted super-adjacency matrix according to the coupling weights within and between different layers, and the stability model of IoBT is analyzed and derived. Finally, an example of IoBT network is given to provide a reference for analyzing the stability factors of IoBT network.

Technical Program

Aerospace Systems Engineering

Model-Based Structured Requirements in SysML

Daniel R Herber and Jayesh Narsinghani (Colorado State University, USA); Kamran Eftekhari-Shahroudi (Woodward, Inc., USA)

Architecture-centric practices are gaining widespread acceptance in systems engineering (SE). This process involves capturing the structure, behavior, and rules and their relationships to create an abstract representation of a system, often termed a model of the system. Central to the rules that govern a system are the requirements that are placed on it, often by various stakeholders These requirements help guide the system development process of a complex entity. In this paper, we discuss an approach for extending the idea of structured requirements (requirements defined through an orderly structure with specific pieces of content that must be filled in) to SysML through customized stereotypes that help enforce the requirement structure through model-based attributes. This approach helps move requirements modeling and management further into the model-based paradigm from the classical textual definitions. In addition, requirements often are customized by the organization defining them through additional attributes. These additional attributes are added to the model-based structured requirement (MBSR) to create a well-defined organizational requirement stereotype. Several examples of the MBSRs are presented using a notional thrust reverser actuation system (TRAS). Several points are made on how this approach can help support more rigorous requirements modeling, analysis, management, and communication throughout the system development process. Future work will involve automatic generation of the textual requirement statements from the attributes, customized validation rules, and customized classifiers for the various attributes.

Tradespace Analysis of Cross-Calibration in Missions Observing Ocean Color

I. Josue Tapia-Tamayo and Paul T Grogan (Stevens Institute of Technology, USA)

Compared to traditional monolithic space missions, distributed spacecraft missions (DSMs) can provide improved temporal resolution of transient Earth phenomena such as algae blooms. However, the miniaturized instruments onboard DSMs may be susceptible to sensor drift or degradation over time. Among different calibration methods used by space missions, this paper investigates cross-calibration methods suitable for DSMs and presents a methodology to explicitly consider cross-calibration during conceptual design phase tradespace analysis. A simulation-based analysis tool based on the Skyfield Python library evaluates constellation cross-calibration performance and estimates mission cost. An application case considers a hypothetical ocean color observing mission with cross-calibration between DSM constellation members and a monolithic reference satellite. A tradespace analysis study generates Walker delta constellation configurations with between 10 to 19 satellites distributed in four orbital planes. Ocean color observation target regions distribute sample points over the East and West coasts of the United States. Simulation analysis computes the average revisit time between cross-calibration opportunities and estimates the mission cost for each configuration. Results

show constellations with four satellites per plane minimize the revisit time for cross-calibration while minimizing average revisit time for cross-calibration opportunity per million dollars. However, other relevant variables that affect the average revisit time for cross-calibration opportunities were also identified for future investigation.

A new SysML Model for UAV swarm modeling: UavSwarmML

Khalil Aloui (L'Institut Supérieur de Mécanique de Paris SUPMECA, France); Moncef Hammadi (ISAE-SUPMECA & Quartz Laboratory EA7393, France); Amir Guizani (LA2MP (ENIS), Tunisia); Mohamed Haddar (ENIS, Tunisia); Thierry Soriano (University of Toulon, France)

In recent years, autonomous or teleoperated robots have played an increasingly important role in civilian applications. In particular, unmanned aerial vehicles (UAVs) are autonomous aerial robots that come in a wide variety of basic frameworks and particular specifications. Thus, a swarm of UAVs is a collection of aerial vehicles that work together to achieve a specific goal. However, the design of UAVs swarms is a complex process. Therefore, in this paper, we propose a continuous approach to the design a swarm of UAVs based on the model-based systems engineering (MBSE) method. This approach consists of three design levels; the swarm modelling level, the swarm simulation level, and the swarm implementation level. Indeed, we have created a new Systems Modeling Language (SysML) model using Domain Specific Language (DSL) to model the swarm mission, the hardware specifications of the UAV swarms, and the software implementation of the swarm system. We called this model "UavSwarmML". Subsequently, we used in the simulation phase Robot Operating System (ROS) as a middleware to simulate and implement our swarm system to validate the developed models. A case study of an autonomous UAV swarm flight mission was chosen to validate this design approach and illustrate its contributions to the efficient design of UAV swarms.

Simulation of Ordering Processes across different Supply Chain Tiers in the Aviation Industry

Hongxu Wang (TUHH, Germany); Sylvia Melzer (Universität zu Lübeck, Germany)

There is increasing concern that previous system development, characterized by the design of an isolated system with a limited number of interfaces to other systems, will be disadvantaged and have a detrimental effect on competition because recent rapid developments in the global supply chain have increased the need for digital services built on multiple interacting systems and their communication. Platforms are one of the most widely used services for sharing information by integrating multiple interacting systems into a network. The current platform integrates these systems with tight coupling to meet a new level of customer requirements.

With the rapid increase in the information traffic along the global supply chain, many companies in the aviation industry have been confronting with these issues of processing and storing data within and across the enterprise. More and more companies are adopting an Enterprise Resource Planning (ERP) system. Which consists of a set of fully integrated modules to support a company's business processes that run from a single database.

Nowadays, the database structure in the ERP system is customized for each company by external vendors. The aviation industry is characterized by a large network and long supply chains with the few Original Equipment Manufacturers (OEMs) and many suppliers (Tier 1, Tier

2, Tier 3). Individually created databases with own terms within the company make an inter-company exchange only possible with high effort.

In this paper, we show how to model and simulate ordering processes across different supply chain tiers in the aviation industry rapidly to validate the use cases concerning the communication structure during a requirements-based engineering process.

MBSE Challenges in the Concurrent Preliminary Design of CubeSats: Nanospace Study

Sophia Salas Cordero, Thibault Gateau and Rob Vingerhoeds (ISAE-SUPAERO, France)

In this paper, the early endeavours of the incorporation of a Model-based Systems Engineering (MBSE) approach to the open-source Nanospace framework is discussed, presenting the challenges that need to be overcome for such an integration. Nanospace is a web application dedicated to facilitate concurrent engineering during the preliminary design phase of CubeSats.

CubeSats provide a progression of educational and research opportunities, and have had increased the accessibility to space for non-space fairing nations. CubeSats and their subsystems interfaces have been studied numerous times. Nevertheless, it is often found that although during previous designs the interfaces between CubeSat subsystems have been studied, each project is started from zero. This work aims to address how system models can enrich Nanospace. It also raises the question of whether the current structure of the database behind the Nanospace user interface needs to be expanded to include certain relations from system models in order to improve change traceability, which can be done through graphs or design structure matrices.

Nanospace may benefit from MBSE, as MBSE facilitates knowledge reuse; which could allow a faster design convergence and faster inspection of candidate architectures. There should not be a need to start a project from scratch when there is available information. All of this is illustrated on a use case example from the preliminary design of the CubeSat Radiation Environment Monitoring Experiment (CREME), a project of ISAE-SUPAERO and ONERA.

Development of Simulation Framework for Impact Analysis of Launch Delays on Lunar Base Station

Luis Daniel Otero and Giulio Cristello (Florida Institute of Technology, USA)

Humans have not ventured beyond Earth since the days of the Apollo missions. NASA astronauts were the first and last to set foot on the lunar surface, and it is again thanks to NASA that the initiative to go back to the Moon is moving forward. The Artemis missions will land men and women on the lunar surface with the purpose of establishing a long-term presence on the Moon. The current Artemis Plan includes the Artemis Base Camp, a lunar base stationed on the lunar South Pole. The maintenance of the base will require frequent missions to be performed in order to keep its supplies stocked and to rotate the crew aboard. Planning these missions around the multiple components needed to be launched, the limited launch windows for transfers to lunar orbit, and the risk of delays, is a task well-suited for a discrete event simulation model. The delay of a launch by even a small number of days can push it outside of the window of opportunity for rendezvous with the lunar Gateway. Therefore, this study aims at developing a systems modeling framework to simulate the impact that launch delays can have on the successful support of a base station, and its crew, on the surface of the Moon. The framework includes the consumption and resupply of multiple types of resources and astronauts with

different mission lengths inhabiting the base, as well as a chance of emergency missions being requested. The data derived from this model will be useful for the long-term planning of support missions to the lunar base.

Autonomous Aerospace Systems

Reinforcement Learning based System-of-Systems Approach for UAV Swarms Behavioral Evolution

Ramakrishnan Raman (Honeywell Technology Solutions Lab, India); Anitha Murugesan (Honeywell International Inc, USA)

Advances in Unmanned Aerial Vehicle (UAV) technologies have enabled the development of biologically inspired swarms or fleets of UAVs that need to collaborate optimally to achieve objectives of a common mission such as in surveillance and remote sensing applications. Typically, such swarms comprise homogeneous UAVs that are identically developed to serve the same purpose using same algorithms and models. However, the recent proliferation of sophisticated autonomous UAVs developed by numerous government and commercial organizations, using varied machine learning models to serve diverse purposes, has surfaced the need to design swarms with heterogeneous UAVs. The challenge with heterogeneous UAVs to operate in swarms is the need to adapt their behavior and collaborate towards common mission objectives despite differences in their learning models and algorithms associated intelligence. In this paper, we present a novel approach to develop swarms of heterogeneous UAVs as System-of-Systems (SoS), and enabling behavioral evolution and adaptation of constituent system UAVs through Reinforcement Learning (RL) algorithms. The proposed approach involves SoS-Constituent System Measures Of Effectiveness Relationship (SSMR) model that correlates the Measures Of Effectiveness (MOEs) for the SoS in relation to the MOEs of the constituent systems. We use RL algorithm to inculcate adaptable intelligence in constituent UAV systems to adapt their behaviors in tandem with the evolution of emergent behavior at the heterogeneous swarm SoS level. By augmenting the reward mechanism of RL through SSMR, the proposed approach incorporates an Intelligent-Behavior Evolution Agent (I-BEA), with the necessary

constraints to learn to maximize the SoS and system-level MOEs, while adapting itself to the evolution in the swarm SoS. The initial experimental results indicate that our approach adequately trains these independent agents to be used in heterogeneous swarms.

Autonomous Systems

A Distributed Control Architecture for Resource-constrained Autonomous Systems

Aaron Hunter (University of California, Santa Cruz, USA); Pavlo Vlastos (USA)

The use of autonomous systems is burgeoning in the world today for many applications in many fields from scientific, industrial, to military. At the same time, advances in semiconductor technology have enabled ever smaller, complex and dedicated microprocessors. This work details a control system architecture that takes advantage of these advances for use in resource-constrained autonomous systems. The architecture consists of a real time hardware controller, a guidance and navigation computer, and an edge TPU for machine learning inferences. While the latter two processors are commercially available, a dedicated, modular real time controller is not. Therefore we present an open source design for a real time controller that is intended to be adapted to many types of autonomous systems. We present three different vehicle platforms that implement this control system including a ground vehicle, a surface vessel, and a quadcopter. Finally, we present results using this control architecture on a few key topics of interest in autonomous systems. The first is a novel spatial estimation algorithm called partitioned ordinary kriging that is designed for resource-constrained systems and can be used for path finding during mapping missions. The second result pertains to a sensor calibration utilizing sensor data collected from the real time controller and performed on the navigation computer. Finally, we demonstrate using the edge TPU (tensor processing unit) for object detection using an onboard camera and an object detection algorithm using machine learning.

Towards an Ontology That Reconciles the Operational Design Domain, Scenario-based Testing, and Automated Vehicle Architectures

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Mastering a specified operational design domain (ODD) and the continuous increase in automation both require comprehensive perception, prediction, and planning algorithms, thus sophisticated automated vehicle (AV) system architectures. Scenario-based testing is emerging as a promising technique

attempting to efficiently run tests on all critical situations for AVs' verification and validation. ODD, AV architectures, and scenario-based testing represent three evolving development worlds with their specific characteristics, peculiarities, and point of view, which must be consolidated and harmonized to enable a seamless design, verification, and validation process. For that reason, this paper proposes an ontology aiming at consistently reconciling the worlds of ODD, AV architectures, and scenario-based testing utilizing cross-relationships. Consequently, the ontology-based approach offers systematic guidance for an ODD definition, the design of a vehicle system architecture for automated driving, and the derivation of corresponding scenario-based test cases during the development process according to the V-model. A case study including the use case "follow lane on a motorway" for the lateral control of an active lane keeping system is exhibited, applying the introduced ontology. Therein it is also shown how the

ontology-based approach enhances test efficiency and incremental development. The paper concludes by highlighting the corresponding advantages and limitations of the presented work.

Finite State Markov Modeling of C-V2X Erasure Links For Performance and Stability Analysis of Platooning Applications

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Cooperative driving systems, such as platooning, rely on communication and information exchange to create situational awareness for each agent. Design and performance of control components are therefore tightly coupled with communication component performance. The information flow between vehicles can significantly affect the dynamics of a platoon. Therefore, both the performance and the stability of a platoon depend not only on the vehicle's controller but also on the information flow Topology (IFT). The IFT can cause limitations for certain platoon properties, i.e., stability and scalability. Cellular Vehicle-To-Everything (C-V2X) has emerged as one of the main communication technologies to support connected and automated vehicle applications. As a result of packet loss, wireless channels create random link interruption and changes in network topologies. In this paper, we model the communication links between vehicles with a first-order Markov model to capture the prevalent time correlations for each link. These models enable performance evaluation through better approximation of communication links during system design stages. Our approach is to use data from experiments to model the Inter-Packet Gap (IPG) using Markov chains and derive transition probability matrices for consecutive IPG states. Training data is collected from high fidelity simulations using models derived based on empirical data for a variety of different vehicle densities and communication rates. Utilizing the IPG models, we analyze the mean-square stability of a platoon of vehicles with the standard consensus protocol tuned for ideal communication and compare the degradation in performance for different scenarios. We additionally present some initial theoretical results that shed some light on the connection between the independent identical distributed (i.i.d.) modeling approach which neglects the time correlations in links and the proposed Markovian approach.

Multi-robot Autonomous Exploration and Map Merging in Unknown Environments

Luiz E. Santos Araújo, Filho and Cairo L. Nascimento, Jr. (Instituto Tecnológico de Aeronáutica, Brazil)

In mobile robotics, autonomy is obtained by navigating an environment while using embedded sensors to estimate a map and the robot position with respect to this map. This problem is known as Simultaneous Localization and Mapping (SLAM) and has been extensively addressed for the single-robot case in the last few decades. However, when the environment becomes larger, a multi-robot solution for the SLAM problem is more efficient despite the increased complexity and the development of new problems, such as multi-robot coordination.

This work aims to develop and implement a solution for the SLAM problem using multiple ground mobile robots. To accomplish that, each robot must autonomously explore part of the

environment and their individual estimated maps must be merged into a single global map. The proposed solution uses a scan matching-based SLAM framework known as GraphSLAM to estimate pose and map for each individual robot. To autonomously explore the environment, the solution proposes the use of map segmentation via Voronoi Graphs, which generate collision-free paths and possible target points for exploration. Map merging is performed when robots rendezvous to take inter-robot measurements to provide relative position information. In order to validate the proposed approach, experiments using simulated and real robots were carried out to autonomously explore and map indoor environments.

Real world experiments presented satisfactory results for a laboratory environment and the proposed rules for coordination as well as the map merging approach worked as intended.

Comparing EKF, UKF, and PF Performance for Autonomous Vehicle Multi-Sensor Fusion and Tracking in Highway Scenario

Kaiqiao Tian, Micho Radovnikovich and Ka C Cheok (Oakland University, USA)

Extended Kalman Filter (EKF), Unscented Kalman Filter (UKF), and Particle Filter (PF) are three popular algorithms to address obstacle position estimate and tracking problems. However, as technology develops, autonomous vehicles pursue a better understanding of the environment and higher safety driving. Different modern sensors are mounting on the car, such as three-dimensional Light Detection and Ranging (LiDAR) and Radio Detection and Ranging (Radar). Sensor fusion from various data types can improve the position estimate accuracy and challenge the traditional tracking algorithm. In order to explore which tracking algorithm has better performance in multi-sensor data fusion (MSDF) and multi-target tracking (MTT) problems, this paper implements and analysis EKF, UKF, and PF algorithm for an autonomous vehicle with three LiDAR and two RADAR in a highway scenario. Our first contribution is processing the point cloud data for each sensor and using a bounding box data type to normalize individual obstacles. Then we designed a tracking system that can switch EKF, UKF, and PF tracking algorithms. Third, we use different state vector update matrices for LiDAR and RADAR for position updates and speed updates. Actual highway driving data are recorded, and a Robotic Operating System (ROS) model is built for algorithm development and result analysis.

Systematization of Relevant Road Users for the Evaluation of Autonomous Vehicle Perception

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Specifying the perceptual accuracy autonomous vehicles require when interacting with surrounding traffic participants is not a trivial task. While computer vision capabilities have drastically improved over the last years (mainly driven by the success of machine learning techniques), specification of corresponding validation goals is lagging behind. A particular challenge is to take criticality of errors into consideration when evaluating perception components. In the context of autonomous vehicles in urban areas, criticality is linked to the varying relevance of environmental elements. Non-detection of leading vehicles or close lane markings is more critical than missing a parked vehicle which has already been passed. In this paper, we propose an approach for the systematic definition of relevant areas in urban traffic situations. Corresponding objects inside these relevant areas can be considered relevant to

enable a more precise perception evaluation. To that end, we introduce a set of basic areas and explain when these become relevant and how these are constructed. Moreover, we show a first implementation of our proposed basic areas and evaluate them based on traffic situations. Additionally, we demonstrate applicability of our method by incorporating it into an exemplary perception evaluation. We hope that our approach can serve as a stepping stone to more precise specifications of perception requirements and task-oriented perception evaluation.

Complex Systems

Multilayer network modeling and stability analysis of Internet of battlefield things

Haihao Ding (National University of Defense Technology, China); Qingsong Zhao (National University of Defense Technology & College of Information System and Management, China)

Intelligent service network under the paradigm of the Internet of Things (IoT) uses sensor and network communication technology to realize the interconnection of everything and real-time communication between devices. Under the background of combat, all kinds of sensor devices and equipment units need to be highly networked to realize interconnection and information sharing, which makes the IoT technology hopeful to be applied in the battlefield to interconnect these entities to form the Internet of Battlefield Things (IoBT). This paper analyzes the related concepts of IoBT, and constructs the IoBT multilayer dependency network model, then constructs the weighted super-adjacency matrix according to the coupling weights within and between different layers, and the stability model of IoBT is analyzed and derived. Finally, an example of IoBT network is given to provide a reference for analyzing the stability factors of IoBT network.

Cyber Security

How to divide a permission token in the delegation process of blockchain-based access control for IoT

Jeonghwa Heo, Heewoong Jang and Heejo Lee (Korea University, Korea (South))

These days, the use of IoT devices is rapidly increased over the world, being utilized for a wide range of industries, such as smart factories, smart cities, health care, while the scope is continuously broadened. However, there are several security issues that stem from the characteristics of IoT devices. One of the major issues that are actively discussed is access control. Traditional access control model like RBAC, ABAC is centralized, which means that all the information for access control stored in one centralized server and validation of access rights by a centralized entity. The property leads to a single of point failure problem. If an IoT network that addresses sensitive information such as related health gets hacked, it could cause a significant leaking of private information incident. Therefore, there have been various works to solve the problem by introducing a decentralized architecture based on blockchain technology, which is called blockchain-based access control (BBAC). However, most BBAC models consider just only a simple access control situation, excluding any change of the access rights. This paper proposes a new access control model considering various situations such as the division and modification of rights, which was usually future work of the previous research.

A Privacy-Preserving Data Aggregation Scheme for Fog/Cloud-Enhanced IoT Applications Using a Trusted Execution Environment

Newton Carlos Will (Federal University of Technology - Parana, Brazil)

The use of IoT devices is increasingly present in our daily lives, as they offer many possibilities for developers and the industry to develop applications, taking advantage of their connectivity capabilities, low cost and, often, small size. As the use of these applications is continuously increasing, the concerns about the privacy and confidentiality of the data generated by these devices also increases, since many applications share the collected data with fog and cloud servers, due the computational constraints of the edge devices. Fog and cloud environments are used to aggregate and analyze data collected by multiple devices, allowing to summarize them and offer personalized services to the users. As IoT devices can collect sensitive data from users, such as personal and behavioral information, it is crucial to handle such data ensuring the privacy of their owners. Privacy-preserving data aggregation schemes are proposed in the literature, but many of them are limited to specific functions and homogeneous data or to specific contexts, such as smart metering and e-health. This paper proposes a generic data aggregation scheme that takes advantage of Trusted Execution Environments (TEE) to ensure the data and user privacy, allowing to process heterogeneous data and to perform complex computations, including the use of machine learning algorithms.

Is It Safe? Identifying Malicious Apps Through the Use of Metadata and Inter-Process Communication

Rodrigo Lemos and Tiago Heinrich (UFPR, Brazil); Carlos A Maziero (Federal University of Parana State - UFPR, Brazil); Newton Carlos Will (Federal University of Technology - Parana, Brazil)

In recent years, the growth in the number of threats on Android has contributed to increasing user awareness and concern about security-related concepts. Due to the predominance of Android, the attacks present on the platform have also evolved, and new strategies for identifying threats are needed. A popular way to identify threats is the use of intrusion detection systems, which can exploit different strategies to carry out threat identification. Static analysis strategy aims to identify malicious apps by scanning their source code, and dynamic analysis uses the behavior monitor approach to classify benign and malicious apps. These two strategies can also be combined in a hybrid approach. This paper focuses on a hybrid strategy to identify threats in Android systems through the use of static metadata extracted from applications and dynamic data from inter-process communication, in order to train machine learning models to perform threat identification. Three machine learning algorithms were used to verify the efficacy of our strategy. Our approach showed to be viable, with the results presenting an identification rate of around 87%, demonstrating that the proposed model has benefits in identifying threats in Android mobile devices. We also point out attributes that differ between malicious and benign apps and highlight the impact on the use of inter-process communication to identify threats.

General Process Detection Through Physical Side Channel Characterization

Michael Taylor, Mitchell A Thornton and Eric Larson (Southern Methodist University, USA)

Physical sensors present in modern Systems-on-a-Chip (SoC) provide a rich source of side channel information that can be exploited to detect and characterize processes running concurrently on the device. Sensor data is periodically collected and machine learning classifiers are employed that predict the types of processes running under a variety of processor load conditions. Experimental results evaluate a number of different classifier models and identify the best types of classifiers for four different general process types; i) file I/O, ii) CPU/ALU intensive, iii) network I/O, and iv) virtualization. The process characterization classifiers are evaluated under a range of processor load conditions varying from light loads to heavy loads to ascertain their effectiveness in the presence of other concurrent and benign processes. Our results indicate that some process classes are less sensitive to background load conditions versus others and our suggested classifier architectures are devised to account for this variability. The detection of file I/O and CPU/ALU-intensive processes are shown to exhibit very high efficiency and robustness with respect to background load conditions. Virtualization process detection is shown to exhibit high accuracy under light loads with moderate degradation observed as load conditions increase. Network I/O detection is shown to have the lowest accuracy due to the relatively small number of sensors present in the network interface card of the system under evaluation.

Cyber Analytics for Intrusion Detection on the Navy Smart Grid using Supervised Learning

Preetha Thulasiraman (Naval Postgraduate School, USA)

The Naval Facilities Engineering Command (NAVFAC) deployed its own Smart Grid in 2019, allowing shore commands to modernize their energy infrastructure. With the addition of new "smart" technology comes additional risks in the form of cyber-attacks. Supervised machine learning is an effective, foundational approach to detect anomalous traffic. In this paper we implement a Bayesian classification and supervised machine learning algorithm for cyber threat detection in the Navy smart grid. We explore how the data set, size of training data and number of features affect classification accuracy. Our experiments were performed using seven data

sets, developed through the University of Montreal using a SCADA sandbox similar to that of the Navy Smart Grid. Three data sets contained nominal data, and four data sets contained malicious cyber-attacks. Our experiments, performed using MATLAB, show that malicious packet distribution within the data set and size of the training data greatly affected classification accuracy. Through our experiments, we show that cyber attacks that send a high volumne of malicious packets can be identified with high accuracy and in real-time to immediately address the intrusion. This paper establishes a baseline of research that demonstrates the utility and operability of machine learning for use in the Naval Smart Grid environment.

Analyzing the Ransomware Attack on D.C. Metropolitan Police Department by Babuk

Emily Caroscio, Jackson R Paul and John Murray (Miami University, USA); Suman Bhunia (Miami University, Ohio, USA)

Ransomware attacks are a fast-growing cybercrime that pose a large threat to society. These attacks can result in losing significant amounts of data and money for their victims. Many industries such as aerospace, governmental organizations, etc., have been targeted in the last couple of years. This paper examines the recent attack incidents by one of the famous ransomware groups, Babuk, on the aerospace industry and a police department. It provides an in-depth analysis of the methodology of the attack and examines the impact at a local and global level. A total of 250 gigabytes of data were stolen from one of the victims, the D.C. Metropolitan Police Department. Babuk first had to gain access by infiltrating the system to attack the victims successfully; however, there is no clear evidence on how this was specifically done. Babuk likely gained access by scanning for vulnerable ports in the victim's system, sending employees a phishing email with a malicious link, or cracking passwords that the victim used for admins in their system. After gaining access, Babuk had to maintain access while stealing and encrypting files. Finally, they demanded ransom from the victims and threatened to post the sensitive data if the ransom was not paid. The attack has impacted not only specific organizations but also public security officials. This paper provides an in-depth analysis of the possible attack methodologies and defense strategies against such ransomware attacks. The defense strategies may include changing government policies, regulating cryptocurrency, and adhering to FBI-listed advice.

Decision-Making for Complex Systems

Comparison of Pattern Recognition Approaches for Identification of Failure-prone Battery Cells

Rudy Pirani and James Cale (Colorado State University, USA)

Maintainability is a system design attribute that encompasses both reliability and the ease and cost-effectiveness of maintaining a deployed system to achieve its technical performance requirements in a cost-effective manner. Battery systems are used as critical power sources in many advanced military and commercial platforms (e.g., aircraft, electric vehicles, submersibles). These platforms require high reliability and operational availability despite undergoing extreme mission profiles, which may also be conducted in geographically remote locations. Unscheduled maintenance from failures and less-than-optimal preventative maintenance planning for on- board battery systems can have a significant impact on the total lifecycle cost (LCC) of the entire fleet. It is therefore desirable to develop new methods to enhance the maintainability of battery systems operating on these platforms. This paper compares three numerical classification algorithms in terms of their accuracy in performing classification for pre-screening battery cells as part of a pre-acceptance qualification program: support vector machine (SVM), linear discriminant analysis (LDA), and principal component analysis (PCA) pre-processing followed by LDA (PCALDA). The paper augments previous research which examined only one classifier, the simple generalized classifier (SGC). Key findings of the paper are that the SVM, LDA, and PCALDA all outperformed the SGC in terms of overall classifier accuracy in a numerical study. The PCALDA is shown to yield the greatest overall classifier accuracy (97%), while LDA is shown to give the greatest accuracy (98%) in identifying failure-prone cells. Based on these observations, the SVM, LDA and PCALDA methods are potentially promising candidates to perform battery cell pre-screening classification.

Machine Learning Algorithms for Labeling: Where and How They are Used?

Teodor Fredriksson and Jan Bosch (Chalmers University of Technology, Sweden); Helena Holmström Olsson (Malmö University, Sweden); David Issa Mattos (Volvo Cars, Sweden)

With the increased availability of new and better computer processing units (CPUs) as well as graphical processing units (GPUs), the interest in statistical learning and deep learning algorithms for classification tasks has grown exponentially. These classification algorithms often require the presence of fully labeled instances during the training period for maximum classification accuracy. However, in industrial applications, data is commonly not fully labeled, which both reduces the prediction accuracy of the learning algorithms as well as increases the project cost to label the missing instances.

The purpose of this paper is to survey the current state-of-the-art literature on machine learning algorithms that are used for assisted or automatic labeling and to understand where these are used. We performed a systematic mapping study and identified 52 primary studies relevant to our research.This paper provides three main contributions.First, we identify the existing machine learning algorithms for labeling and we present a taxonomy of these algorithms. Second, we identify the datasets that are used to evaluate the algorithms and we provide a mapping of the

datasets based on the type of data and the application area. Third, we provide a process to support people in industry to optimally label their dataset.The results presented in this paper can be used by both researchers and practitioners aiming to improve the missing labels with the aid of machine algorithms or to select appropriate datasets to compare new state-of-the art algorithms in their respective application area.

An approach of decision support system for drift diagnosis in cyber-physical production systems

Adama Arama and Eric Villeneuve (ESTIA Recherche, France); Christophe Merlo (ESTIA & ESTIA Institute of Technology, University of Bordeaux, France); Laura Laguna Salvado (ESTIA Recherche, France)

Despite the development and application of new digital solutions in the production industry, the human operator is still essential in the production chain monitoring and control processes. In this context, some activities can be crucial for the human operator like, for example, drift diagnosis in production control process. It requires attention and experience and can be assisted by Decision Support System (DSS) to guide operators in decision-making in industrial production process control. Drift diagnosis process is a challenging problem in this context and artificial intelligence technologies are promising to tackle this issue. In this paper, we propose a new approach of DSS for drift diagnosis. The proposed approach is built upon a literature review on drift concept, drift detection methods and failure diagnosis approaches. This multi-model approach is designed to address all the diagnostics tasks of production systems and is based on Machine Learning (ML) algorithms to model the behavior of production systems, a knowledge-based model to integrate human experiences and a data-driven model to combine historical data from sensors. When the drift occurs, the proposed DSS can help human operator to determine drift causes and to suggest corrective actions. This article also provides guidelines about the design of a decision support system to support human operators in complex decision activities.

Healthcare Quality Improvement: The Need for a Macro-Systems Approach

Inas S. Khayal (Geisel School of Medicine at Dartmouth, USA)

While the structure of healthcare systems evolved out of the need to address acute conditions, the function of healthcare systems evolved to primarily address chronic conditions. The healthcare delivery system organically developed to respond to "one-off" acute illness or injury. Subsequently, healthcare delivery systems grew into legacy systems that evolved into complex systems over time. Healthcare delivery for acute conditions tends to utilize a specific part or form of the healthcare delivery system. In contrast, healthcare delivery for chronic conditions forces patients to seek care over time between different places or healthcare entities. Because of the self-contained structural organization of these healthcare delivery systems, they were not designed to provide coordinated, integrated, and longitudinal care over time and place. Consequently, today's complex legacy healthcare delivery system requires significant improvement in the quality of care delivered to patients, especially those with chronic conditions. As a complex and legacy system, the most appropriate approach to improve the quality of delivered care is through a re-design quality improvement process, rather than a new system design process. In this paper, we describe the conceptual framework for quality improvement (QI) and the current micro and macro level approaches to quality improvement. We applied the current quality improvement approaches to the QI conceptual framework. We identified the

limitations in current quality improvement processes in complex healthcare systems at the macro-level, pointing to the need for macro-systems approaches to healthcare quality improvement.

Context-Aware Recommendation Systems Using Consensus-Clustering

Dina Nawara and Rasha Kashef (Ryerson University, Canada)

Recommendation Systems (RSs) have proved a compelling performance to overcome the data overload problem. Context-aware recommenders guide users/clients to more personalized recommendations. Incorporating contextual features in recommendation systems improves the systems' accuracy; however, they still suffer from sparsity and scalability problems which impact the quality of recommendations. In this paper, to overcome these limitations, we propose a context-aware recommendation system using the notion of consensus clustering, named CARS-CC. The proposed recommendation system is experimentally evaluated using contextual Pre-filtering and Post-filtering approaches. Experimental results show that the concept of consensus learning using clustering analysis can significantly improve the recommender systems' accuracy. The proposed method surpasses the other recommendation algorithms in terms of accuracy, precision and recall, particularly using the Hybrid Bipartite Graph Formulation (HBGF) method. In addition, CARS-CC(hgpa) has outperformed all other clustering techniques in terms of MAE and RMSE with 23.73% and 7.54%, respectively. The MAE and RMSE results show that consensus clustering leads to better accuracy measures and a more stable resilient recommendation system. The response time taken to generate recommendations using post-filtering is less than that of the pre-filtering approach. The CARS-CC(HGPA) in the post-filtering approach; generates recommendations 58.4% faster than pre-filtering, which speeds up the recommendation process and facilitates real-time response.

A Robust Deep Learning Model for Predicting the Trend of Stock Market Prices During Market Crash Periods

Alireza Ghasemieh and Rasha Kashef (Ryerson University, Canada)

The stock market is one of the most important investment opportunities for small and large investors. Stock market fluctuations provide opportunities and risks for investors. However, some fluctuations are considered as enormous threats for most investors; significantly when the stock market has fallen sharply due to external factors and does not reach its previous point in a long time. For example, at the beginning of 2020, financial market indices, especially the stock market, fell sharply due to the COVID-19 pandemic, and for a long time, the indices did not grow significantly. Many investors suffered huge losses during this period. Although much research has been done in stock market forecasting and very efficient models have been proposed so far, no special effort has been made to build a model resistant to the collapse of financial markets. We propose a Convolutional Neural Network (CNN)-based ensemble model that is highly resilient to the stock market crash, especially at the beginning of the COVID-19 period. The proposed model not only avoids losing money in financial crises but can bring significant returns to investors. Experimental results show that the ensemble CNN models using Gramian Angular Fields (GAF) has greatly improved the resistance of the model in critical market conditions.

Asymmetric Change-of-Probability Measures for Tail Risk Management

Saeede Enayati (University of Massachusetts Amherst, USA); Hossein Pishro-Nik (University of Massachusetts, Amherst, USA)

Large (extreme, high-impact) events can occur in complex systems as a result of fat-tailed distributions of the system behavior. Decision-making in the presence of a potential high-impact event where the law of large numbers (LLN) cannot be applied, is not as straightforward as decision-making in a normal scenario where the LLN is used. In this paper, a general framework is introduced for decision-making in the presence of a potential high-impact event using change-of-probability measures. The idea of the proposed framework is to weigh the high negative consequences of non-LLN decision-making problems as a tail risk management strategy. The proposed approach is named asymmetric change-of-probability measures (ACM) as the right and the left tails of the distributions are treated asymmetrically. A key to this approach is to define and satisfy required properties so that the change-of-measure operation is performed in a principled way. An important property is ensuring upper bounds for the relative entropy between the distributions. We first introduce asymmetric bounded expectation (ABE), as a special case of the general approach. We then extend the proposed asymmetric method to the general change-of-measure. Benefiting from the same properties as the symmetric change-of-measure, we show that the asymmetric approach can be potentially a promising method for decision-making under non-LLN risk management circumstances in complex systems. Through a practical example from venture capital (VC) in finance, and in comparison, to the symmetric change-of-measure, we show that considering tail risk management will result in a different decision-making outcome where the VC is required to invest in more startups to avoid a loss.

Defense System

Evaluation of the Data Distribution Service for a Lossy Autonomous Hybrid System

Preetha Thulasiraman (Naval Postgraduate School, USA); Yu Kheng Denny Cheng (Singapore Defence, Singapore); Bruce Allen (Naval Postgraduate School, USA)

The implementation of US Naval autonomous systems requires a unified, cohesive communications protocol that can be used by all network assets. The Data Distribution Service (DDS) is a prime candidate for such cohesive communications. This paper assesses the performance of DDS in a network architecture that fits a specific Naval use case scenario. We modeled a Naval use case system architecture that incorporates Satellite Communications (SATCOM) and WiFi links to test the ability of DDS to execute cohesive communications between the network nodes within constraints of the scenario setup. We use a network emulator, Mininet, to set up the network parameters and investigate the throughput and latency performance of network links across various data sample sizes. We also conduct simulations to evaluate how simultaneous multi-flow data (traffic data running in parallel within the network nodes) contend for the network resources and impact performance. DDS security settings are toggled for different simulation runs to understand the network performance impact of authentication and encryption. Through extensive simulations, we show that DDS provides robust, cohesive communications for different link types. We also provide recommendations on how network metrics should be manipulated to increase throughput, reduce latency and minimize the impact of data loss.

Energy Management and Sustainability, including Renewable Energy

Design and Accuracy Assessment of a Multi-Input Single Ended Primary Inductor Converter (SEPIC) for Highly Efficient Output from Hybrid Sources of Renewable Energy

Tahmin Mahmud, Sheikh Mustahsin Ahmed Rakeen, Afrid Uddin Araf, Nayeem Ahmed and A. K. M Abdul Azad (Brac University, Bangladesh)

In this thesis, a hybrid topology of an off-grid energy-harvesting system (by integrating Solar Photovoltaic (PV) Module with Bicycle Dynamo Generator) using a DC-DC multi-input single-output (MISO) single-ended primary inductor converter (SEPIC) has been proposed for isolated islands. A conventional SEPIC based SISO converter circuit was designed for the boost mode operation and its performance was compared with our proposed hybrid topology of the SEPIC based MISO converter system. The prototype of the proposed hybrid system has been developed by following an optimum design approach for small-scale performance analysis. The MISO SEPIC circuit has been designed to be operated at a practical input voltage of DC 12.1 V and an approximate output voltage of DC 53 V with 10W output power at the load side. To get the maximum voltage at the output end, the operating duty cycle for the proposed converter circuit is recorded as 81.49% with a gain of 4.4. We obtain and calculate an efficiency rate of 91.6% for the proposed prototype from the hardware analysis and field-test data. A detailed and rigorous investigation of the proposed topology has been carried out through software simulation using MATLAB while considering the Solar PV Panel as Source-I and a feedback-controlled Bicycle Dynamo Generator as the Source-II. Different intermittence conditions, solar irradiance, seasonal variation, day-night behavior, power outage and other factors were considered while performing both the hardware and software analysis. Moreover, to better understand the maximum performance of the two renewable energy sources, separate outdoor analysis was performed for the Solar PV Panel and the Bicycle Dynamo Generator. Solar energy has been a promising tool as inexhaustible and clean energy for decades. From off-grid small installations to large scale photovoltaic plants, solar energy has become an integral part of our life. Due to the vicissitudes of atmospheric behavior, the PV Module alone can not harvest optimum electrical energy from the sun. So, this is where our proposed topology stands out. Our proposed model instills the possibilities of renewable energy, with the hope that it would ultimately reduce the total demand from the national grid and ensure utter energy efficiency inside Bangladesh and beyond.

Extracting Atmospheric Water using Peltier Effect Powered by Solar Energy with Contribution from Piezo-Materials

Mohammed Thushar Imran, Azraf Nafi Barshan, Sharif Mohd Shams and Rahat Tajwar (BRAC University, Bangladesh); Labiba Zahin and A. K. M Abdul Azad (Brac University, Bangladesh)

The progressing world has innumerable problems and the needs of people are increasing rapidly. The shortage of electricity and clean water is one of the most alarming issues of the present times. This paper describes the design of an atmospheric water generator system powered by renewable energy sources. The atmospheric water generator (AWG) consists of a Peltier module associated with two heat sinks and a DC Fan. A solar panel is used to charge up a DC lead-acid battery and to power up the atmospheric water generator; a constant supply to the atmospheric water generator is ensured by the assistance of a charge controller. Alongside,

piezoelectric elements that are mounted under a tile, light up a digital voltmeter-ammeter display that shows the load voltage and current. This paper includes a complete process of electricity generation from piezoelectric elements and solar PV panel distinctly. It also incorporates a comparative study of power contributions from the Piezo elements and Solar Panel. Both Hardware and Software design models are considered to optimize the performance of renewable energy harvesting systems. Moreover, the efficiency of water generation with the Peltier effect is depicted through multiple field test results. Finally, a comparative study between the present work and other contemporary research is established based on the water cumulated from the AWG during the field experiments.

Estimation of Hourly Utility Usage Using Machine Learning

Albert Wong, Chun Chiu, Abigail Abdulgapul and Mirza Beg (Langara College, Canada); Youry Khmelevsky (Okanagan College, Canada); Joe Mahony (Harris SmartWorks, Canada)

The COVID-19 pandemic has had a major impact on the usage of various utilities. To assess the impact, this research explores the (baseline) estimation of hourly utility usage if the pandemic did not happen. Using usage data from Harris SmartWorks, various machine learning algorithms are implemented to show that they are effective in modelling hourly usage patterns, calendar effects, as well as “lingering” effects of the exogenous factors and produce accurate results.

Machine Learning Models Application in Daily Forecasting of Hourly Electricity Usage

Albert Wong, Puja Unni, Andre Henrique, Tuan Nguyen and Chun Chiu (Langara College, Canada); Youry Khmelevsky (Okanagan College, Canada); Joe Mahony (Harris SmartWorks, Canada)

Traditional time-series techniques produce forecasts on future values based on the trend or seasonality of past values. It is not easy for these techniques to consider the impact of other exogenous and calendar-related variables. This paper uses the electricity usage data from Harris SmartWorks to demonstrate an approach to building and training machine learning models to overcome this problem. It is shown that Machine learning models produce accurate daily forecasts for hourly usage. The performance of these models could be evaluated by one conventional metric, and one explicitly built for articulating the model’s forecasting accuracy for peak periods.

Engineering Systems-of-Systems

A SysML-based Function-Centered Approach for the Modeling of System Groups for Collaborative Cyber-Physical Systems

Alexander Hayward and Maximilian Rappl (Helmut Schmidt University, Germany); Alexander Fay (Helmut-Schmidt-Universität, Germany)

Cyber-physical systems (CPSs) are able to collaborate with other CPSs in their environment at runtime. Such collaboration, which contains a suitable combination and aggregation of the individual functions of different CPSs, makes it possible that goals can be jointly achieved that the individual CPS would not have been able to achieve on its own. As part of the collaboration at runtime, the collaborative CPSs, which may come from different manufacturers, form temporary system groups in which they assume different roles and associated responsibilities. The possibility of collaboration originates from the technical progress in the field of information technology and can be found in several domains. This paper presents a domain-independent function-centered approach that enables the modeling of such system groups at the design time of the single collaborative CPS and thus serves as a basis for cross-manufacturer collaboration planning. The approach describes in 6 steps how the constitution and the behavior of the system group with its participants can be modeled with the help of functions and independent of specific components. The modeling is based on SysML, which has been extended to be able to express aspects of the system group. The extended modeling elements of SysML are presented and explained within the description of the approach.

PropS: Towards Proprioception in Cyber-Physical Production Systems by Means of Collaborative Localization

Jan-Felix Klein, Constantin Enke and Maximilian Ries (Karlsruhe Insitute of Technology, Germany)

Cyber-physical production systems (CPPS) are a key concept of Industry 4.0 in which heterogenous assets collaborate by sharing data via a network. In this paper we conceptualize and implement PropS, a proprioception system, which forms a global knowledge graph by gathering and interpreting distributed pose information from different assets of a CPPS. Pose information of the internal asset structure as well as detected objects of interests are shared in a standardized way to ensure seamless integration of new assets. We implement an asset administration shell submodel to define the necessary data structures. PropS enables collaborative localization by integrating distributing sensor information exceeding individual asset boundaries. The presented system can, e.g., reason about the docking pose for an autonomous mobile robot in a dynamically changing environment which is unknown to the robot and inferred from multiple cameras distributed over multiple assets. We implement PropS and the presented framework with real-world robots and sensors that use the Robot Operating System (ROS). The communication between the assets is realized with the Open Platform Communication Unified Architecture (OPC UA). The feasibility of the system is verified with a proof of concept experiment. We further provide current limitations and ideas for future work to unfold the full potential of PropS.

QoE Evaluation of Real-Time Remote Operation with Network Constraints in a System-of-Systems

Cedrik Schüler, Tim Gebauer, Manuel Patchou and Christian Wietfeld (TU Dortmund University, Germany)

With the advent of robotics, remote operation gained momentum as it allows for the control and feedback of distant systems, thus reducing human logistics and risk. Despite the growing popularity of fully autonomous systems, remote operation still retains a significant relevance due to operative requirements like manual overrides in critical situations. Such a requirement calls for a robust and reliable remote operation experience. We propose an evaluation system following a system-of-systems architecture to assist in the development of remotely operated applications with tested resilience against network effects. The system has an extensible architecture allowing the swap of real and virtual components and enables the evaluation of remote operation applications in unreliable network environments. In a proof-of-concept study, the system is implemented and used to evaluate the impact of network constraints on a teleoperated high-speed driving simulation. Our results show that the baseline setup leads to approximately equal (± 0.9 %) end-to-end driver performances. Thus, other evaluations are primarily affected by additional constraints, enabling our system for extensive analyses. Comprehensive drive trials show that network latency steadily mitigates driving performance, whereas packet loss can be compensated well up to a specific value. In addition, our Quality of Experience (QoE) surveys show the subjective ratings of participants exposed to network impacts.

Making Model-based System Design aware of design requirements: Challenges in using and extending SysML

Mara Nikolaidou, George Dimitrios Kapos and Anargyros Tsadimas (Harokopio University of Athens, Greece)

Model-based system design is served by a single, multi-level system model supporting all design activities, in different levels of detail. SysML, the OMG standard introduced in 2007, provides the means for defining such models to system designers. Over this period, SysML, currently in its 7th edition, has been adopted by both the academia and the industry and is moving towards its second version. However, engineers are still skeptical towards SysML. Studies revile that some of the main reasons identified by engineers are a) there are no user-oriented methodologies to facilitate its use, as many of them claim "it is still to expensive and unmanageable", b) there is a lack of automation and integration with external tools and c) domain-specific profiles are not widely available.

To promote SysML usage in model-based design, in this tutorial we discuss our efforts to establish a model-based approach for system design focusing on the exploitation and verification of design requirements expressed in a quantitative fashion. SysML extensions to handle and compute complex non-functional requirements, such performance, quality or cost and verify their support by system components. To this end, a consistent fashion to describe requirements and their verification formulas shall be presented. The presented framework provides for the automated integration of external tools for simulation, model analysis and decision-making during system design. All information created by external tools during system design is integrated within SysML system model, while the system designer only interacts with SysML to perform all engineering activities. External tool characteristics (for example simulation

language) as well as detailed, low level information (for example simulation results) are hidden from the designer. To accomplish this, provision of libraries within SysML and domain-specific languages DSLs (profiles) is necessary, as well as a high degree of automation. To this end, we propose some extensions to SysML to promote system design process focusing design requirements.

Participants will be provided with a brief overview of SysML and the proposed methodology, an introduction to the usage of external tools and the necessary SysML extensions. Furthermore, two domain-specific profiles, based on the proposed concepts, will be analytically presented. One related to the operation of railway transportation system and one to the design of Cyber-physical Human Systems (CPHS).

Healthcare 4.0 - Managing a Holistic Transformation

Jameela Al-Jaroodi (6001 University Blvd., USA); Nader Mohamed (California University of Pennsylvania & Middleware Technologies Lab., USA); Nader Kesserwan (Robert Morris University & School of Engineering, Mathematics and Science, USA); Imad Jawhar (Al Maaref University, Lebanon)

Healthcare systems have evolved quickly with the introduction of information communication and technologies (ICT) and the digitization movement. Recently, these systems are going through further transformations to digitalize healthcare services and introduce smartness culminating into what is currently dubbed “Healthcare 4.0”. Efforts to introduce Healthcare 4.0 and create effective and smart healthcare services has significantly increased. A Healthcare 4.0 infrastructure will not only make healthcare services smart and highly available, but it will create the necessary framework that will allow healthcare systems to expand their capabilities quickly and efficiently. Unfortunately, much of the efforts to transform and digitalize healthcare systems are isolated and apply different approaches, tools, technologies and models. In addition, there are many integration and compatibility issues across different healthcare systems especially among systems that already exist and proposed new ones. As a result, it becomes increasingly difficult to integrate them or support collaboration across the disjoint healthcare systems to achieve the Healthcare 4.0 vision. We believe that a unified vision and a strategic approach to implementing Healthcare 4.0 is necessary and that long-term planning will help reduce some of the issues and create more systemic capabilities to connect current systems, integrate new ones and add advanced functionalities and smart capabilities. In this paper, we discuss the challenges facing these efforts and the importance of using a strategic approach to manage the healthcare systems transformation and adopt healthcare 4.0.

Environmental Systems

An autonomous bird monitoring and food intake recording feeder system towards effective rehabilitation

Vinay Chandrasekhar (Pennsylvania State University, USA); Praveen Kallam and Jayanthi Kallam (Avian and Reptile Rehabilitation Center, India); Madhav Rao (International Institute of Information Technology - Bangalore, India)

Rehabilitation for avians is generally examined by veterinary doctors and till date not much technological intervention is attempted to address recovery phase of birds in group. Different breed of birds are usually aggregated at a confined place and nurtured for recovery. However, in a group, the growth of birds is usually dominated by the stronger and larger sized avians, thereby making the other birds vulnerable even to the extent of succumbing to death due to continuous lack of food. Hence a continuous monitoring of individual birds around the feeder system is necessary and if needed additional attention is recommended to specific birds who are on the verge of food lapses. The existing high cost video surveillance system has capability to detect birds via markers, but requires additional sensory information or high focus camera to calibrate food intake. The proposed system design demonstrates selective monitoring of birds and approximately quantifies the food intake by the individuals in a group of the rehabilitation. The robust and low cost feeder design includes customized array of coils forming RFID system to identify and localize birds within the feeder system, and array of weight sensors interfaced to microcontroller to estimate the food intake. The weight sensors are optimally placed in the feeder system to

extract the food consumed by the avian. The microcontroller is further connected to microprocessor to transfer the food intake data and the information of the identified birds that visited the feeder system for further offline processing. The designed feeder system was deployed in Avian and Reptile Rehabilitation Center, and experimental results showcased promising results in identification of birds and food intake records.

Visualization System Suite for Global and Hyperlocal Air Quality Awareness

Adrian Rusu and Amalia Rusu (Fairfield University, USA); John Williams (The Weather Company, an IBM Business, USA); Kourosh Karimkhany (IBM, USA)

When people think of deadly environmental conditions, rarely do they consider air quality. Yet, according to the World Health Organization, poor air quality kills 3 to 5 million people annually. Most existing air quality alerts monitor the Air Quality Index (AQI). This air quality measure is often filled with data that is too complex for even most meteorologists to interpret, meaning that the everyday person (who is impacted the most) has a very limited understanding of it. Developing a new system to monitor and relay air quality alerts to people in a consistent, easily interpretable way, will raise awareness related to heavy air pollution, especially helping those people with breathing disorders. By presenting air quality information to users, they will be aware of pollution around them and can make better decisions to reduce health risks. We collect real-time data to determine the AQI from air quality sensors around the world and create a system suite to display the data in various visualization formats such as monochrome heatmaps, avatars, and augmented reality for mobile devices. People are able to inquire about hyper-accurate air quality alerts and

statistics, based on their selected location. This paper describes methods, tools, and results of visualizing air quality in different formats utilizing data that is generated by multiple sensor APIs. User evaluations, which are employed throughout our study to validate user-friendliness, are also illustrated in detail.

Large-Scale Systems Integration

ChaordicLedger: Digital Transformation and Business Intelligence via Data Provenance and Ubiquity

Michael F Marchini (Villanova University & Lockheed Martin, USA)

Digital Transformation manifesting as the revitalization of business operations and procedures allows companies to realize greater efficiency and significantly increased customer value; by questioning existing processes and remaining aware of procedural shortcomings, actionable ideas are captured and implemented. The direction of a company's procedural revolutions is driven by Business Intelligence that considers the needs of the customer, the needs of the product, and the needs of the employee. These three considerations are rooted in how the product is produced, delivered, maintained, and proven to remain relevant. By maintaining relationships between relevant specifications and test execution evidence in the distributed and automated Evidence Management and Auditing platform known as SpaceChain, transparency is afforded to all stakeholders in product development and fine-grained change estimates become available to customers without requiring deep domain-specific knowledge. Further, new and existing employees and partnering business entities may use the artifacts stored in this platform to immediately appreciate the complexities and scope of any given product, regardless of whether development is ongoing, was recently completed, or was completed long ago. The provenance and protection of critical objects like specifications and test evidence is afforded through Smart Contracts that embody and enforce tailorable business rules, while artifact ubiquity is provided by a permissioned distributed file system.

Emulation Framework for Distributed Large Scale Systems Integration

Neena Imam, Nageswara Rao, Anees Al-Najjar, Thomas Naughton and Seth Hitefield (Oak Ridge National Laboratory, USA)

Recent trends in systems engineering include integration of very large-scale systems. Significant systems integration challenges need to be overcome when these large-scale systems are dispersed geographically. In these scenarios, intelligent integration of distributed large-scale systems requires significant coordination among hardware elements, as well as all software components. The approach of integrated systems (both computing platform and experimental equipment) for end-to-end orchestration is called federation. Virtual frameworks can aid in the testing, assessment, and implementation of a functional system of interconnected resources. We present an emulation framework that replicates the software environments of multi-site federations of computing systems and instruments. Our emulation framework allows systems engineers to reduce development cost and avoid disruptions to production infrastructure. Our framework was effectively used to develop and test software modules for various tasks including container orchestration and instrument access. For performance assessment, however, the emulated framework is severely limited in providing accurate network and IO measurements at 10 Gbps and higher data rates. The data transfer performance profiles estimated using these emulated measurements are usually inaccurate for high bandwidth and high latency connections, since emulation does not accurately reflect the critical network transport dynamics. We utilize measurements from a physical testbed with hardware network emulators to obtain data transfer profiles that closely match the expected profiles for the

emulated federations. We show the effectiveness of our approach by an illustrative example of integrated (federated) multi-site ultra large scale systems that are connected via high speed wide area networks.

Medical Systems

A Real-Time Seizure Classification System Using Computer Vision Techniques

Pavan Kumar Pothula (International Institute of Information Technology, Bangalore, India); Sriram Marisetty and Madhav Rao (International Institute of Information Technology - Bangalore, India)

Epilepsy is one of the most common neurological disorders, affecting 50 million people worldwide. Despite the availability of numerous anti-epileptic drugs, it is often impossible to control the disease effectively. Lack of supervision and failure to provide urgent medical care may be detrimental to the life of the patient. Hence a portable edge computing and seizure classification device to aid medical staff and provide appropriate and timely treatment to the patients is desirable. Conventionally, seizure detection is considered as a signal processing problem with electroencephalogram (EEG)as the primary source of a time-varying signal. The EEG signal acquisition system puts the patient under observation with a lot of discomforts owing to a large number of physical connections of electrodes on the patient's head. A video-based portable system not only eliminates the physical connections and contacts to the patient but also has the capacity of monitoring a large group of patients in-side a controlled care unit. This paper proposes a novel architecture for the detection and classification of facial seizures of type Gelastic and Dacrystic, from the video data of the patient. The developed two-layered architecture was deployed on a portable Jetson Nano board and an accuracy of 98.8% in detection and classification of Gelastic and Dacrystic seizures was obtained. The best inference latency of 13.6 seconds was characterized on the deployed board.

Development of a Visualization Tool for Healthcare Decision-Making using Electronic Medical Records: A Systems Approach to View a Patient Record

Georgia A. Mandell and Matthew B. Keating (Dartmouth College, USA); Inas S. Khayal (Geisel School of Medicine at Dartmouth, USA)

Healthcare delivery systems are widely accepted as socio-technical systems. Unlike other socio-technical systems, healthcare systems leave very little decision-making to technical automation and control. Instead, the healthcare delivery system relies on human healthcare resources for decision-making. Human decision-making is imperative to the clinical delivery of care to patients and to the operational processes that support care delivery, quality improvement, and other organizational management activities. For these clinical and operational activities, human resources make healthcare decisions using healthcare data typically housed in electronic medical records (EMRs). Unfortunately, EMR systems were first designed with the functional capability to store data, and, second to a lesser degree, to retrieve data. The literature recognizes the need to improve the retrieval of information from EMR systems. More specifically, there remains the need to directly view a patient’s holistic health and healthcare trajectory. At this time, decision-makers are left to mentally build this holistic picture in their mind by sequentially clicking through many sections of the EMR. Therefore, in this paper, we develop a visualization tool to organize and present an individual’s health and healthcare trajectory by describing a patient record holistically from a system architecture perspective. This approach is based on a previously developed system model for healthcare delivery and individual health outcomes.

An Investigation on the Role of Affordance in the Design of Extended Reality based Environments for Surgical Training

Avinash Gupta (Oklahoma State University, USA); J. Cecil (Oklahoma State University & Cyber Tech LLC, USA); Miguel Pirela-Cruz (Texas Tech Health Sciences Center, USA); Rittika Shamsuddin, Shelia Kennison and Christopher Crick (Oklahoma State University, USA)

This paper focuses on new types of affordances which can impact the HCI based design of Extended Reality (XR) based training environments. XR is an umbrella term used to describe Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) training environments are presented. In the context of HCI, the objective is to study the role of affordances in impacting the training outcomes in terms of comprehension and skills acquisition. New affordances are proposed along with a categorization under visual and haptic affordance. The notion of dynamic affordance is also proposed. The impact of these affordances on comprehension and skills acquisition is discussed in the context of a surgical procedure called condylar plating surgery (which is performed to treat the fractures of the femur bone). A genetic algorithm-based approach to help in surgical planning is also discussed, which can be integrated with the training activities. The results of Assessment activities on the acquisition of skills and knowledge during interactions with the training environments is also discussed.

Model-Based Systems Engineering

Model-Based Systems Engineering for the Design of an Intermodal High-Speed Freight Train Terminal

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Since rail traffic is the mode of mass transport with minimal transportation related greenhouse gas emissions, it plays a key role in achieving the sustainability targets of the transportation sector. To enable a modal shift from road to rail the German Aerospace Center has developed the Next Generation Train CARGO, a high-speed freight train concept targeted to ship so-called Low-Density High Value goods on existing railway infrastructure from smart city to smart city. Studies have revealed that an intermodal transshipment terminal is key to a successful integration of the concept in current logistics networks. Driven by high requirements regarding handling, reliability, and time, the terminal is a complex intralogistics system strongly depending on the particular good group that shall be handled. This work uses the principles and methods of Model-Based Systems Engineering in a tailored modeling approach to specify a generic terminal system architecture. Based on this system architecture an exemplary good-specific variant of the terminal is derived with focus on intralogistics freight handling. The chosen design approach is further evaluated regarding its suitability in context of intralogistics system design. The results of this work demonstrate that Model Based Systems Engineering is capable of successfully guiding architecture specification in the novel application domain of complex intralogistics facilities and further contributes to a consistent and comprehensive terminal design.

Model-based Systems Engineering Papers Analysis based on Word Cloud Visualization

Mengru Dong (Beijing Institute of Technology, China); Jinzhi Lu (EPFL & Beijing Zhongke Fengchao Ltd, Sweden); Guoxin Wang (Beijing Institute of Technology, China); Xiaochen Zheng (EPFL - École Polytechnique Fédérale de Lausanne, Switzerland); Dimitris Kiritsis (EPFL, Switzerland)

With the continuous improvement of system scale and complexity, model-based system engineering (MBSE) is of great importance in the practice of system engineering (SE). MBSE has been widely concerned in industry, especially in the field of complex equipment. At the same time, in academia, research articles about MBSE come into being and grow rapidly. In this paper, keywords and full-texts of 143 high quality articles related to MBSE field are extracted from relevant journals of IEEE and INCOSE communities, and the research contents of MBSE field are visualized and analyzed by using a third-party Python WordCloud library. The research focuses on: (a) identifying related concepts of MBSE; (b) exploring research contents of MBSE; (c) analyzing three pillars of MBSE: modeling languages, methods and tools based on articles. The results show that MBSE plays an important role in realizing system architecture design and developing system architecture models by applying modeling technology to support system requirements, design, analysis and evaluation, verification and validation in the whole life cycle of product development. SysML and OPM are the most popular modeling languages and

modeling methods in MBSE research field respectively. This paper provides a technical route reference for exploring the current research field of MBSE by using WordCloud text analysis which is helpful to predict the future research of MBSE.

A Conceptual Model based Systems Engineering (MBSE) Framework for Digital Twins

Aditya Akundi (University of Texas at Rio Grande Valley, USA); Viviana Lopez (University of Texas Rio Grande Valley, USA)

A Digital Twin is an interactive, real time digital representation of a system or a service utilizing onboard sensor data and internet of things technology to gain a better insight in the physical world. With the increasing complexity of systems and products across many sectors, there is an increasing demand for complex systems optimization. Digital twins vary in complexity and are used for managing the performance, health, and status of a physical system by virtualizing it, among many others. The creation of Digital Twins (DT) enabled by Model-based Systems Engineering (MBSE) has aided in increasing system interconnectivity and simplifying the system optimization process. More specifically, the combination of MBSE languages, tools, and methods has served as a starting point in developing digital twins. This article discusses how MBSE has previously facilitated the development of digital twins across domains, emphasizing both the benefits and disadvantages of adopting an MBSE enabled digital twin creation. Further, the article expands on how various levels of digital twins were generated via the use of MBSE. An MBSE enabled conceptual framework for developing digital twins is identified that can be used as a research testbed for developing digital twins and optimizing systems and system of systems.

A Semantics Modeling Approach Supporting Property Verification based on Satisfiability Modulo Theories

Jingqi Chen (Beijing Institute of Technology & None, China); Jinzhi Lu (EPFL & Beijing Zhongke Fengchao Ltd, Sweden); Guoxin Wang (Beijing Institute of Technology, China); Lei Feng (KTH Royal Institute of Technology, Sweden); Dimitris Kiritsis (EPFL, Switzerland)

Property verification in Model-based systems engineering (MBSE) supports the formalization of model properties and evaluates the constraints of model properties to select an optimal system architecture from alternatives for trade-off optimization. However, there is a lack of an integrated method that property verification enables to be applied in multi domain specific modeling languages, which is not conductive to the reuse of property verification for different architecture and may increase the learning and use cost. To solve the problem, a semantic approach combining a unified modeling method GOPPRRE modeling method with Satisfiability Modulo Theories (SMT) is proposed to realize property verification. The syntax of the multi-architecture modeling language KARMA based on the GOPPRRE modeling method is extended to realize property verification based on Satisfiability Modulo Theories, which enables the KARMA language to verify the models by evaluating the constraints which are defined based on the model properties. The proposed approach supports the evaluation of property constraints defined by different modeling languages for trade-off optimization in a unified language. The approach is evaluated by a case of optimizing the matching between workers and processes in a multi-architecture modeling tool MetaGraph which is developed based on KARMA. From the result, such approach enables to evaluate constraints consisting of properties and select an optimal scheme from the alternatives.

Enabling Mission Engineering through a Reusable Digital Engineering Environment

Michael J Pennock (The MITRE Corporation, USA); Gabriela I Driscoll, Judith S. Dahmann and Meg P Adams (MITRE Corporation, USA)

Mission engineering is the deliberate organization and integration of a system of systems (SoS) to achieve a particular goal or mission. As such, it often requires the consideration of many alternative configurations of independent constituent systems and organizations over a diverse set of operating contexts with a focus on the achievement of desired mission outcomes. While digital engineering approaches and tools would seem to be a natural means to aid engineers in managing the associated complexity, mission engineering poses several challenges to its successful application. Among these challenges are the diversity of SoS constituents, complex system behaviors and interactions, and multiple relevant levels of abstraction. The direct consequence is that each mission may require a different characterization of the SoS architecture and corresponding set of simulation models. This paper presents an approach developed at the MITRE Corporation to partially mitigate these challenges by constructing a reusable digital engineering environment based on a shared modeling framework. The digital engineering environment leverages a multi-layered SysML architecture model that evolved through its application to multiple, real-world mission engineering efforts. The layered structure enables the reuse and rapid construction of new mission architectures and facilitates the coordination of multiple analysis efforts using different simulation tools.

Online Model based Systems Engineering (MBSE) Bootcamp: A Report on Two Day Workforce Development Workshop

Aditya Akundi (University of Texas at Rio Grande Valley, USA); Oscar Mondragon (University of Texas at El Paso, USA); Mayra Ortiz-Galarza (University of Texas Rio Grande Valley, USA); Tzu-Liang (Bill) Tseng (University of Texas at El Paso, USA); Sergio Luna Fong (The University of Texas at El Paso, USA); Viviana Lopez (University of Texas Rio Grande Valley, USA)

To aid the integration of Model-Based Systems Engineering (MBSE) within current industry and the challenges faced, introducing MBSE concepts, tools, and languages through academia or workforce development workshops can increase the plausibility of a streamlined transition from document-centric approach to MBSE frameworks. This paper reports on an online model-based system engineering bootcamp conducted in collaboration with The University of Texas Rio Grande Valley and The University of Texas at El Paso. The importance of MBSE is emphasized throughout the online bootcamp to a diverse group of audience i.e., students, faculty, and industry professionals unfamiliar to systems engineering. A set of predefined questions through pre and post bootcamp surveys aided in determining the perceptions of MBSE and the effectiveness of the bootcamp in increasing the knowledge of MBSE amongst participants. A positive knowledge gain was observed on the importance of systems modeling and MBSE across all the participants categories i.e., students, faculty, and industry personnel indicating the effectiveness of the online bootcamp. A set of open-ended questions were targeted specifically for industry professionals from manufacturing, aerospace, healthcare, transportation, and software domains attending the bootcamp for capturing the perceived challenges and obstacles according to them for implementing Model-Based Systems Engineering in their organizations.

Model-based Development of a Federated Database Infrastructure to support the Usability of Cross-Domain Information Systems

Sylvia Melzer (Universität zu Lübeck, Germany); Hagen Peukert (Universität Hamburg, Germany); Hongxu Wang (Hamburg University of Technology, Germany); Stefan Thiemann (Universität Hamburg, Germany)

The Centre for the Study of Manuscript Cultures (CSMC) at the Universität Hamburg hosts a steadily growing number of autonomously developed databases. These databases often run in heterogeneous hardware and software environments and use different, project-specific data models. These conditions lead to a high degree of autonomy but to an increasing heterogeneity. The heterogeneity then leads to the problem that these databases cannot be easily merged into a federated database system (FDBS). In general, a FDBS integrates multiple autonomous database systems into a single FDBS. The challenge is now to merge multiple heterogeneous systems into one FDBS to provide successful federated searches. Here, the term successful means that the results of a search query are correctly and completely answered by all integrated domain-specific database systems. In addition to delivering correct and complete results from these queries, semantically and syntactically correct mappings of various database schemes must be ensured.

We argue that at the faculty of the Humanities, a cross-domain use of autonomously developed databases offers added value in terms of data analysis and evaluation. Hence, the challenge that exists is to develop a suitable federated database infrastructure that supports the development of autonomous information systems, while heterogeneity does not increase. To meet this challenge, in IT projects in the defense sector and in the public administration of the federal government, the V-model is a mandatory procedural standard to develop IT systems systematically. When developing a cross-domain information system, special attention should be paid to the development of variants, i.e. the project-specific information systems, so that the extension of the federated infrastructure at the faculty is guaranteed and can be maintained in the long term. In the area of Model-based Systems Engineering (MBSE) variant modeling is a very current topic and no standard exists. However, there are some approaches that can be used, such as the method Variant Modeling with SysML (VAMOS). VAMOS is characterized by its ease of use to model variants and can be combined very well with other methods. In this paper we present a model-based approach to develop a federated database infrastructure for supporting the usability of a cross-domain information system. For the development of a federated database infrastructure we present how the V-model can be combined with the VAMOS method using the tool Cameo Systems Modeler for modeling and simulating in general, the broker-based SysML Toolbox for simulating database interactions, and the database management system Heurist for creating a cross-domain information system.

System-wide Dynamic Modelling and Performance Metrics of an Acoustic Exponential Detector

Stephane Blouin (DRDC, Canada)

Multiple passive acoustic detectors exist for under/above-water applications, such as defense, mammal monitoring, etc. Implementations involving exponential filters have also been tested. However, the literature provides little guidance about their tuning, which may be non-intuitive. This is especially true considering how much dynamical features such filters may introduce. To alleviate this shortcoming, this publication first reviews the key configuration parameters of such a detector. Then, after conjecturing that ROC (Receiver Operational Curve) curves may not be appropriate for this task, this publication proposes the development of new global, that is

system-wide, and dynamical performance metrics meant to facilitate the overall tuning. Event though theoretical derivations and the computation of new global dynamical metrics are presented, this publication remains focused on practical aspects. Of interest to practitioners, the impact of configuration parameters is studied. Many examples demonstrate how the proposed closed-form expressions adequately approximate performance based on simulated and real data. The same examples are used to discuss how ROC's may not apply. Also, a thorough summary of the main results and their implications is provided. Of particular relevance is the influence matrix developed between configuration parameters and performance metrics. Moreover, results presented here indicate the necessity for optimization among many performance metrics and configuration parameters.

Perceptions and the extent of Model-based Systems Engineering (MBSE) use - An industry survey

Aditya Akundi (University of Texas at Rio Grande Valley, USA); Wilma Ankobiah (University of Texas Rio Grande Valley, USA); Oscar Mondragon (University of Texas at El Paso, USA); Sergio Luna Fong (The University of Texas at El Paso, USA)

Model based Systems Engineering (MBSE) supports the development of complex systems through capturing, communicating, and managing system specifications with an emphasis on the use of modeling languages, tools, and methods. It is a well-known fact that varying levels of effort are required to implement MBSE in industries dependent on the complexity of the systems a given industry is associated with. To understand the current state of perception on what MBSE is and the use of MBSE among different industry clusters, this paper we survey industry professionals nationally from Defense, Aerospace, Automotive, Consultancy, and Software and IT industry clusters. The survey conducted allows a comparison of how MBSE is defined, advantages on the use of MBSE, the project types and the specific life cycle stage MBSE is applied, along with the adoption challenges, as reported by the survey participants across the aforementioned industry clusters - with an objective of triggering discussions in MBSE community for identifying strategies to address MBSE related challenges tailored to a specific industry type.This analysis could further act as a leeway in identifying strategies for addressing MBSE related challenges tailored to a specific industry type. Another benefit is for organizations to learn from other domains, potentially adopting and leveraging successes, mitigating myths and biases.

Information Management of a Lifeline Infrastructure for Mobility of People and Goods

Rayshaun L Wheeler, Cody Pennetti and James H. Lambert (University of Virginia, USA); Tom Polmateer (UVA, USA); Geraldine Jones and Yogesh Dhanapal (Virginia Department of Transportation, USA)

Intermodal logistics among other critical infrastructure systems relies on principled management practices to prevent catastrophic failures and improve long-term planning solutions. These practices face several challenges with respect to information management. While data is continuously collected and artifacts are produced, the unstructured storage and dissemination of data will inherently degrade an organization's knowledge repository. A fractured state of organizational data will impede strategic investments by constraining a system's resources. Transportation infrastructure includes additional challenges because they are composed of dispersed physical assets that must consider spatial association and interdependencies. To mitigate these challenges, an organization can embrace a centralized knowledge repository that

integrates geospatial features of physical systems and organizational process assets. This paper describes an innovation that achieves geospatial operations management and data analytics, which has been implemented for a multi-disciplinary transportation agency. The system provides stakeholders (e.g., local community, international freight carriers, multimodal transportation planners, maritime ports, system operators, et al.) with tools and information that support the management of project planning, costs, resources, risk, communication, and procurements with a geospatial model-based application. The application serves as the primary knowledge repository that supports multi-criteria decision analysis of transportation system operations. The innovation is demonstrated for a transportation agency responsible for more than 90,000 km of road infrastructure, 7000 personnel, 400 annual infrastructure projects, and an annual operating budget of more than 7 billion USD.

Mind Maps Upstream SysML v2 Diagrams

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Over the past two decades, the promoters of Model Based Systems Engineering (MBSE) have encouraged systems engineers to transition from document-centric approaches to model-based ones. Literacy of systems engineers in reading, sharing and elaborating models has therefore become an issue. Whatever the modeling language, elaboration of models is a highly complex intellectual process and SysML is no exception. Feedback from industry practitioners and MBSE lecturers suggests that developers of SysML models often stumble on the same problem: thinking about the system before modeling it in SysML. The authors of this paper propose to ease that elaboration process by using mind maps. With their graphic form and rather flexible way of organizing ideas, mind maps turn out to be a good candidate to help thinking about the system. Unlike approaches that directly switch from mind maps to SysML diagrams dedicated to one specific system, this paper introduces an intermediate step: mind maps first enable elaboration of diagrams patterns. The latter may in turn be instantiated onto one or several systems. Without loss of generality, the proposed approach is step-wise illustrated on real-time systems monitored by software controllers. Patterns are proposed to cover need expression, requirement capture, use case driven analysis and design.

Identifying AI Opportunities in Donor Kidney Acceptance: Incremental Hierarchical Systems Engineering Approach

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The current organ placement process for transplantation is an evolving system of systems with emergent behavior. This highly integrated complex system consists of Organ Procurement Organizations (OPOs), Transplant Centers (TXC), patients, and their interactions. The number of waitlisted kidney candidates is nearly five times the available supply. Unfortunately, over twenty percent of donated deceased donor kidneys (supply) are discarded due to issues with kidney quality. While some of this discard is medically necessary, some represent a lost opportunity. One approach is to develop a decision support system to identify the right candidate for the right donor at the right time and then communicate that analysis to various stakeholders in different locations over time. This paper uses an incremental hierarchical

systems engineering approach to capture the current kidney allocation systems architecture and identify opportunities for an Artificial Intelligence (AI) decision support system to reduce kidney discard. The incremental hierarchical (top to bottom) approach was combined with model-based system engineering (MBSE) to aid in eliciting stakeholders' needs, behaviors, boundaries, and interactions. This approach led to a structured development process for the attractor "reducing kidney discard" and facilitated systematically documenting the opportunity space. Stakeholders reviewed proposed AI decision support systems, ensuring that decision points with more significant opportunities were addressed. Ultimately, the effectiveness of the systems engineering approach is justified with a data-driven deep learning TXC decision support system validated by transplant surgeons. Future work will include developing data-driven models for all stakeholders using current data incorporating the most recent kidney allocation policy changes.

Creating a Digital Twin of an Insider Threat Detection Enterprise Using Model Based Systems Engineering

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Inference Enterprise Modeling (IEM) is a methodology developed to address test and evaluation limitations that insider threat detection enterprises face due to lack of ground truth and/or missing data. IEM uses a collection of statistical, data processing, analysis, and machine learning techniques to estimate and forecast the performance of these enterprises. As part of developing the IEM method, models satisfying various detection system evaluation requirements were created. In this work, we extend IEM as a digital twin generation technique by representing modeled processes as UML Activity Diagrams and tracing solution processes to problem requirements using ontologies. Using the proposed framework, we can rapidly prototype a digital twin of a detection system that can also be imported and executed in systems engineering simulation software tools such as No Magic Cameo Enterprise Architecture Simulation Toolkit. Cyber security and threat detection is a continuous process that requires regular maintenance and testing throughout its lifecycle, but there often exists access issues for sensitive and private data and proprietary detection model details to perform adequate test and evaluation activities in the live production environment. To solve this issue, organizations can use a digital twin technique to create a real-time virtual counterpart of the physical system. We describe a method for creating digital twins of live and/or hypothetical insider threat detection enterprises for the purpose of performing test and evaluation activities on continuous monitoring systems that are sensitive to disruptions. In this work, we use UML Activity Diagrams to leverage the integrated simulation capabilities of Model Based Systems Engineering (MBSE).

Blended Metamodeling for Seamless Development of Domain-Specific Modeling Languages across Multiple Workbenches

Muhammad Waseem Anwar and Federico Ciccozzi (Malardalen University, Sweden)

Design and development of Domain-Specific Modeling Languages (DSMLs) are crucial activities in model-driven engineering. At the core of these languages we find metamodels, i.e. descriptions of concepts and rules to combine those concepts in order to build valid models. Both in research and practice, metamodels are created and updated more or less frequently to meet certain business requirements. Although there exist several workbenches for metamodeling, some textual (e.g., JetBrains MPS) and some graphical (e.g., Eclipse Modeling

Framework - EMF), it still remains a sensitive and complex task, where several stakeholders with different skillsets need to be able to properly exchange ideas and reach agreements.

To maximize the throughput of metamodeling activities, in this paper we propose a Blended Metamodeling Framework (BMF) that enables the development of metamodels through both graphical and textual (natural language) notations interchangeably, by utilizing the concepts of Natural Language Processing (NLP) and model-driven engineering. The feasibility of the framework is demonstrated via the Portable test and Stimulus Standard (PSS) use case, where a DSML is developed by seamlessly blending the use of textual (natural language) and graphical (EMF) notations. Moreover, for demonstration purposes we also generate a domain-specific language structure reflecting the metamodel in JetBrains MPS.

Model Checking Functional Integration of Human Cognition and Machine Reasoning

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Functional integration of human cognition and machine reasoning is an industry-wide problem where failure risks health or safety. Differences in human versus machine functioning obscure conventional integration. We introduce cognitive work problems (CWP) for rigorous, verifiable functional integration. CWP specify the cognitive problem that integrated designs must solve. They are technology-neutral, abstract work objects, allowing people and computing to share and transform them in coordination. The end-to-end method is illustrated on a system that employs AI for remote patient monitoring (RPM) during COVID-19 home care. The CWP specified actionable risk awareness as the medical problem RPM must solve. Graphical modeling standards enabled user participation: CWP as finite state machines and system behavior in BPMN. For model checking, the CWPs logical content was translated to linear temporal logic (LTL) and the BPMN into Promela as inputs to the SPIN model checker. SPIN verified the Promela implements the LTL correctly. We conclude this CWP-derived RPM design solves the medical problem and enhances patient safety. The method appears general to many critical systems.

Modeling and Simulation

Model-based Systems Engineering methodology for defining multiphysics simulation models

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Due to the increasing complexity of the systems to be developed, it is necessary to proceed to an ever more precise modeling. The design of products delivered to customer are driven by industrial criteria grouped under the acronym SWaP-C (Size, Weight and Power and Cost). They must be the smallest, lightest, most energy-efficient, least expensive and most efficient as possible, with even shorter lead times and limited budgets. We identified two main problems in the design of complex systems, the need of a clear interface between Systems Engineering and Model Providers, and an adequate consideration of multi-physics and multi-component interactions. This paper suggests a methodology developed to ensure a consistency between the system architecture and models of physics simulation. This methodology creates a bridge between MBSE and physical simulation discipline by implementing an additional diagram/viewpoint on the ARCADIA method. This viewpoint will specify the models, organize model building and give stakeholders a common document on which they can exchange. It also allows being exhaustive on the interfaces and the physics involved. MBSE allows the understanding of customer needs, an exhaustive definition of system functionalities and setting up a physical architecture that serves as a reference for the construction of the physical simulation model architecture.

Regionalized Modeling of Supply Chain Resiliency for Analyzing Incentive Options

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This work examines the regional effects of COVID-19 supply chain shocks and potential inventory strategies to sustaining overall economic productivity through lockdowns. We introduce a multi-region extension to the economic production model proposed by Pichler, et al. that was used to assess the extent of Covid-related shocks to gross output through modeling the interdependency between regional and national economies at the industry level. Our extended modeling approach aims to optimize, through genetic search, the degree to which the increased inventory supply targets allow for improved economic productivity and the ideal allocation per industry which most efficiently achieves this mitigation. The approach also integrates a new data regionalization procedure which we apply to a case study of the Alabama state economy. This application is shown to identify a set of major manufacturing and service sectors, where additional inventories enable greater sustained productivity across the Alabama region. This regional analysis of the Alabama economy highlighted the importance of sectors such as chemical, petroleum, food and beverage, and vehicle manufacturing and public administration, construction, management, transportation, and healthcare towards maintaining economic productivity. The ability to quantify regional production impacts from inventory allocations is leading to starting points for determining local government policies that target their most sensitive industries.

A System Based on Deep-Learning for Dynamic Routing problems

Jean-Alexis Delamer (St. Francis Xavier University, Canada); Sidney Givigi (Queen's University & Royal Military College of Canada, Canada)

This paper analyzes the use of reinforcement learning with the Proximal Policy Optimization algorithm (PPO) in the context of the Dynamic Travelling Repairman Problem (DTRP). DTRP are routing problems in which one or multiple agents needs to optimize the processing time of dynamically generated requests. The study case of this paper is of a Unmanned Aerial Vehicle with no motion constraints and unlimited sensing that needs to service multiple targets in bounded environments, while minimizing the waiting time of each target. We analyze the performance of two different types of neural networks architecture, a feed-forward network and convolutional neural network (CNN). The performance of each network is analyzed in terms of the number of targets serviced and the average waiting time. Two heuristic policies, 'Nearest-first' (NF) and 'First Generated First Served' (FGFS), are used as baselines to compare the performance of the neural networks. The results show that CNNs perform better than a feed forward network. Differently from the feed forward network, the CNN network is able to capture the spatial features of the environment reducing the average waiting times of the targets. The CNN architecture also shows potential to perform as well as the heuristics. Further work is necessary to extend the proposed solution to other situations.

Early validation of heterogeneous battery systems in the railway domain

Johan Bergelin (Mälardalen University, Sweden); Antonio Cicchetti (Mälardalen University & Västerås, Sweden); Emil Lundin (Inission, Sweden)

In general, trains are referred to as environment friendly transportation means when compared e.g. to cars, busses, or aircraft, being modern trains electrified systems. Unfortunately, the costs due to creation and maintenance of railway infrastructures, notably the overhead lines to power the trains, impose boundaries to their expansion potentials. In this respect, the advances in battery technologies are disclosing new opportunities, like serving partially electrified tracks. In particular, on-board batteries can be used as backup energy where overhead lines are not available. In such scenarios, analyzing battery requirements and evaluating possible solutions is of critical importance. This paper proposes a model-based systems engineering methodology for evaluating the feasibility of heterogeneous battery systems in the railway domain. The methodology leverages separation of concerns to reduce the complexity of the problem and abstracts the different railway system components by means of corresponding simulation models. The methodology is illustrated through a study performed at an industrial partner; in particular, the paper discusses how simulation models have been conceived, refined, validated, and integrated to analyze the properties of various battery configurations for several passenger trains operating on commercial lines in France. Interestingly, the results demonstrate that heterogeneous battery systems provide a suitable trade-off alternative when compared to homogeneous batteries.

A Digital Twin of Battery Energy Storage Systems Providing Frequency Regulation

Nina Kharlamova (Danish Technical University, Denmark); Chresten Træholt (Denmark); Seyedmostafa Hashemi (Technical University Denmark, Denmark)

Battery energy storage systems (BESSs) are an important part of the modern electrical grid. They allow seamless integration of renewable energy sources (RES) into the grid by mitigating the variability of RES power production that depends on the availability of natural resources.

However, a BESS work can be disturbed in various ways, e.g. by equipment fault and cyberattacks. To keep the work of a BESS that provides frequency control services predictable and reliable, a BESS digital twin is proposed in this paper. It supplies the battery owner with an up-to-date battery behavior forecast that can be further applied to intelligent condition monitoring, fault detection, battery management as well as cyberattack detection and mitigation. A digital twin modeling includes three major steps: data gathering, preprocessing, and forecast. The BESS state of charge (SOC) data generated from utilizing real frequency data to a utility-scale BESS providing frequency regulation in the Nordic area is utilized to evaluate the quality of the BESS digital twin modeling. The steps of data preprocessing are tailored for SOC forecast. We proposed a BESS digital twin that forecasts SOC by applying artificial intelligence (AI)-based methods. The demonstrative case study is presented to illustrate the framework implementation for a BESS providing frequency regulation.

Integrating System Dynamics with Data Science via Graphical User Interface

Ange Lionel Toba (Idaho National Laboratory, USA)

This paper builds on the PySD project, which seeks to bring together System Dynamics and Data Science by migrating models into a programming environment in Python. The authors develop an interactive tool, built on top of the PySD module as a step toward accessibility, which helps further the ability of (1) simulation to be intuitive for non-experts and (2) Data Science to facilitate model structure understanding. This tool is meant to serve as a conduit through which Data Science can be leveraged in Systems Dynamics modeling efforts.

Influence of Network Topology on UAVs Formation Control based on Distributed Consensus

Fabrício Costa Souza, Sergio Ronaldo Barros dos Santos and André Marcorin de Oliveira (Federal University of Sao Paulo, Brazil); Sidney Givigi (Queen's University & Royal Military College of Canada, Canada)

In the task of formation control, there are many autonomous agents with detection and communication capabilities, with positions defined in different reference coordinates. Through a consensus algorithm, agents reach a common understanding of information shared locally through a communication topology, allowing UAVs to move while following a reference trajectory and maintaining the desired geometric configuration. Motivated by the fact that the communication topology is essential for the task of coordinating multi-agent systems, in this article we investigate the influence and characteristics of the fixed communication network topology on the distributed consensus performance, considering four communication network models. The simulations are performed using a multi-agent software in-the-loop simulation platform in a ROS/Gazebo architecture for the control and three-dimensional simulation of UAVs and Matlab/Simulink for the implementation and execution of the formation control algorithm based on consensus distributed with a leader-follower approach. We performed simulations for different parameters of the considered network topology models, using the same trajectory and formation shape. We present the results of simulation tests, visually and quantitatively evaluating the performance of the distributed consensus, and relating this performance to the communication network models considered in this work and the metrics extracted from these randomly generated communication topologies

Improving high value manufacturing with simulation-based Bayesian Optimisation

Bruce M Gunn, Imali Hettiarachchi and Michael Johnstone (Deakin University, Australia); Vu Le (Deakin University & Centre for Intelligent System Research, Australia); Doug Creighton (Deakin University, Australia); Luke Preston (Carbon Revolution, Australia)

This paper presents a novel combination of simulation-based optimization for the process operation of a physical factory, with an emphasis of understanding how the optimization results support with design decisions for the evolving system requirements. The study combines a discrete event simulation (DES) and a Bayesian optimizer. The DES models contain multiple input variables, which can be varied to generate model outputs to help with decision making in stochastic, dynamic environments. To this end, optimizing the models output to achieve a maximum or minimum is an integral part of understanding the system performance and guiding design choices. With the absence of a simple (or approximate) mathematical model for describing the system, the simulation models are treated as black-box functions. Sensitivity analysis is a key method for understanding system dynamics of a black-box simulation model. It can be very time consuming and computational expensive, however, when considering complex models with many input variables. Bayesian Optimization (BO) is an attractive alternative which can be used in this context, being sequential and containing self-learning algorithms. In this study we have utilized a model of a manufacturing factory as the optimization testbed. The model contains many stochastic input variables and operates with day-night shift patterns. A subset of input parameters was optimized in the study, to maximize the factory throughput per day. The optimizer was able to produce good overall throughput results and furthermore, BO results were used to generate charts showing the input-output relationship. This enabled a sensitivity analysis of the factory model, against each of the key parameters used in the optimization. The results obtained are in line with those observed in practice and helped inform decisions made within the factory. The method deployed here is easily adapted to other models and is easily modifiable for other optimization techniques.

Degradation Estimation Analysis of an Aeronautical Pneumatic Valve Using Machine Learning

Lucas de A Silva and Humberto Sano (Embraer S.A., Brazil); Cairo L. Nascimento, Jr. (Instituto Tecnológico de Aeronáutica, Brazil)

This work aims to propose a methodology to evaluate machine learning models' capability to estimate the degradation level of an aircraft pneumatic system valve (PRSOV - pressure regulating and shutoff valve) in open-loop. A more accurate PRSOV degradation estimation may reduce operational costs and raise aircraft availability by: supporting the logistics and maintenance scheduling, enabling controller reconfiguration to keep the desired performance or extend the valve end-oflife, and reducing the corrective maintenance costs through faster fault identification. Therefore, the data used in this study were provided by a computational model that considers multiple degradation types simultaneously and adjusted to improve its accordance with the reality by regarding sensor characteristics and operating conditions. Compared with the previous works, the results show that the new input features developed by this work can improve the models' performance, mainly when the measurement uncertainties are regarded, reaching more than 85% of R2 using only features that do not need additional sensors for the aircraft. Furthermore, it was highlighted the importance of properly choosing the excitation vector, whether fast or slow, to stimulate a particular phenomenon. Regarding the applied algorithms, XGBoost generally provides the best results. The main contributions of this work to the PRSOV degradation estimation state-of-the-art are: regard the sensor uncertainty and sampling time, study fast

excitation profiles to reduce the turnaround time, and propose new features to enhance the machine learning models' performance

Robotic Systems

Virtual Commissioning of the Trajectory Tracking Control of a Sensor-Guided, Kinematically Redundant Robotic Welding System on a PLC

Stefan Schütz and Robin Schmidt (Fraunhofer Institute for Mechatronic Systems Design IEM, Germany); Christian Henke (Fraunhofer IEM, Germany); Ansgar Trächtler (Universität Paderborn, Germany)

This article shows the methodical procedure for the model-based systems engineering and virtual commissioning of the motion control of a complex robotic system with 9 axes in the application field of welding automation. By the integration of external sensor technology, the system semi-automatically detects the weld seams of the assemblies to be welded. As part of real-time multi-objective optimization, the system's kinematic redundancy is used during motion execution to avoid singularities and to comply with joint limits, making it easier for the system operator to set up the welding system. The simulation models created in virtual commissioning serve as additional visual support during system setup. This provides an approach to robot-based automation of manufacturing processes in small and medium enterprises, which often fails due to small batch sizes and lack of personnel with robotics skills.

In the full paper, the state of the art of virtual commissioning as well as redundancy resolution via local optimization in the field of robotics is presented. Next, the designed control scheme for sensor guidance and multi-objective optimization of the robot's motion behavior completely running an a programmable logic control (PLC) is presented. Basing on a model-based system

description the virtual commissioning of the complete system with a step-by-step transition to reality using model-in-the-loop and hardware-in-the-loop testing is shown. Finally, the real commissioning is described and successfully completed by welding tests on a component.

Applied Partitioned Ordinary Kriging for Online Updates for Autonomous Vehicles

Pavlo Vlastos (USA); Aaron Hunter (University of California, Santa Cruz, USA)

Autonomous vehicles for exploration purposes are often limited by energy and computational capacity. Often they are tasked with the goal of efficiently and optimally exploring a given region of space. Tasks involving path planning and certain spatial estimation algorithms can require computation time with exponential growth based on the number of measurements taken. This creates a problem if the number of measurements becomes large. An autonomous vehicle, such as a Mars rover may take unnecessary amounts of time to estimate its surroundings, depending on the type of spatial estimation it uses. This can extend mission time which may be problematic. Ideally, such a system should be able to conduct accurate spatial estimates with rapid update rates, with computation time that does not grow exponentially with the measurement count. This paper discusses an experiment to compare a spatial estimation method, ordinary kriging with a proposed method, partitioned ordinary kriging (POK) using real environmental data measured by a remote-operated autonomous surface vehicle (ASV). The ASV collected depth measurements of a small body of water, mapped to its GPS location while under remote-control. The mean absolute error (MAE) and computation time were compared as the number of measurements increased. The POK method demonstrated favorable error and computation time compared to ordinary kriging.

Evaluating Data Representations for Object Recognition During Pick-and-Place Manipulation Tasks

Humberto N Carvalho, Lucas Pontes Castro, Thaís Rêgo, Telmo de Menezes e Silva Filho, Yuri Malheiros and Leonardo V. Batista (Universidade Federal da Paraíba, Brazil); Amilcar Soares and Vinicius Prado da Fonseca (Memorial University of Newfoundland, Canada)

When manipulating objects, robots need to build a description of the environment that is simultaneously global and local. Recognizing objects and estimating their pose are examples of tasks expected from robots to operate in unstructured environments. An efficient solution to this phase has the potential to increase robotic usage in such settings.

This paper presents a study on the representation of tactile and joint-position data to recognize daily objects. We trained and evaluated machine learning models in the object recognition task using different data representations extracted from a publicly available dataset. The results present the statistical significance of the use of descriptive statistics of tactile and joint-position for recognizing objects, even without visual information. Our findings support that tactile data or a combination with joint-position information can be successfully used for object identification during manipulation tasks. The feature engineering approach with descriptive statistics to represent data used in this paper showed promising results regarding recognizing objects using a combination of tactile and joint-position information. Testing different data representations was crucial for improving the recognition of objects from 66.43% of accuracy using an exploratory approach with 3 points to 93.53% of correct recognition using descriptive statistics for the same model, Extra-trees.

Neuro-Fuzzy Grasp Control for a Teleoperated Five Finger Anthropomorphic Robotic Hand

Maxwell Welyhorsky (University of Ottawa, Canada); Vinicius Prado da Fonseca (Memorial University of Newfoundland, Canada); Qi Zhu and Bruno Monteiro Rocha Lima (University of Ottawa, Canada); Thiago Eustaquio Alves de Oliveira (Lakehead University, Canada); Emil M. Petriu (University of Ottawa, Canada)

Semi-autonomous manipulation can expand robot assistants and intelligent prosthesis use to efficiently a more comprehensive range of manipulation tasks. Nevertheless, several aspects of teleoperation, such as misaligned joint control, still restrict robotic manipulation in unstructured environments. This paper presents a novel neuro-fuzzy intelligent control system for human-like grasp behaviours. First, the remote operation of the human-like robotic hand used data collected from a sensing glove. Then, we used grasp synergies to allow each finger to move independently. The data collected enables the evaluation of the proposed Adaptive Neuro-Fuzzy Interface System (ANFIS) to grasp objects with high levels of accuracy. Several aspects were considered to increase robustness: no post-processing of collected data, variations of objects in the tests, and the use of multiple grasp attempts for trained data. The results show evidence that these aspects provided a robust model for remapping a human hand to the robotic system behaviour. The experimental study presented in this paper addresses the efficiency of the ANFIS system to grasp with a high level of accuracy. Merging grasp synergies with the ANFIS machine learning model, developments have been made to further define dexterous machine learning for teleoperation and how they can be used for human-like grasping operations. The results show, for an instance, a normalized root mean square error (NRMSE) of 2.13% of the index finger, which is strong evidence that these aspects provided a robust model for remapping a human hand to the robotic system behaviour.

Robotic Camera Positioning System for Inspection of Tunnels: A Conceptual Design

Ryan D Keizer, Rickey Dubay and Lloyd Waugh (University of New Brunswick, Canada); Cody Bradley (Bradley Engineering Ltd., Canada)

A robotic camera positioning system to aid in the image capture process of the photogrammetric inspection of hydroelectric tunnels is introduced. The system is designed to adapt to tunnels of different and non-constant diameters while providing consistent and high-quality image properties. The system captures high resolution images of the interior surfaces of tunnels to create a detailed 3D model allowing for the remote inspection and monitoring of a tunnel's visual and spatial condition.

The system is based on a three-wheeled mobile platform with an extendable boom capable of reaching the center of cylindrical tunnels up to 10 meters in diameter. An extending arm with a high resolution camera at each end rotates about the center of the tunnel, capturing images of the tunnel surface. The system provides the remote operator with pose and progress information through the incorporation of various sensors. It addresses the limited access many hydroelectric tunnels have with a modular design capable of being compacted, allowing for easy transport of components.

Insight into the features and functionality of the system's design is detailed, including the conceptual design and how it addresses the various objectives and constraints. Models

constructed have been simulated in the process to gather kinematic and dynamic properties which provide means for component selection and model verification.

The design has been developed in alliance with an industry partner with validated experience with photogrammetric inspection of such environments who is confident the proposed design will make a significant improvement to the efficiency, applicability, and ease of the image capture process.

Sensor Fusion for Octagon - an Indoor and Outdoor Autonomous Mobile Robot

Kaiqiao Tian and Khalid Mirza (Oakland University, USA)

Robot and self-driving vehicle navigation and localization problems have been a hot topic in recent years. With the significant development of ranging sensors such as three-dimensional Light Detection and Ranging (LiDAR), Radio Detection and Ranging (RADAR), depth cameras (Microsoft Kinect and Intel RealSense), robot and autonomous vehicles have improved their understanding of the surrounding environment. However, a single sensor can only provide limited information, and robot multi-sensor fusion has offered new perspectives for navigation and localization. Sensor fusion technology can solve two complex problems in robot navigation. Typically, mobile robots only detect above-ground objects for obstacle avoidance. But in the real world, a hole or gap along the robot path can cause damage to the robot and needs to be avoided too. Typically, robot navigation uses a single approach for the solution of the localization problem by using an indoor map or GPS. However, in some cases, robots have to navigate between indoor and outdoor environments and must use different solutions for reliable operation. This paper presents an industry-level autonomous mobile robot that uses the sensor fusion method to solve indoor and outdoor navigation tasks. For safe navigation, a below-ground obstacle detection algorithm is presented that is based on point cloud data provided by the Kinect depth camera, which can then be added to the location of above-ground obstacles provided by the 2D LiDAR SLAM algorithm. A navigation source switching algorithm is designed for switching robot navigation systems using an indoor map and outdoor GPS.

Networking Architectures and Protocols for Multi-Robot Systems in Agriculture 4.0

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Agriculture 4.0 is an important area of research that is evolving very quickly due to the considerable advances in many technologies. Multi-robot systems (MRS) constitute one the most important components that can provide smart farms with the required functions and services to achieve the objectives of increased productivity, efficient allocation of resources, adaptation to climate changes, and elimination of food waste. For example, MRS systems can perform important tasks including seeding, harvesting, checking for disease, chemical spraying and weed control. In this paper, we provide an overview of the networking architectures, and protocols that can be used for MRS systems in agriculture 4.0. We also discuss the various issues and challenges involved in robot-to-robot (R2R) and robot-to-infrastructure (R2I) communication, and provide a case study of UAV-based data collection from WSNs in smart farms.

3D Reconstruction of a Small Dam using a Profiling Sonar and an UUV

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In order to increase the safety and reliability of hydroelectric power plants, autonomous robots are of great interest to perform automated tasks mainly in submerged regions. This work proposes a workflow for the dam inspection operation by creating a 3D reconstruction of the submerged part of the dam from a point cloud generated by a profiling sonar sensor mounted on a Unmanned Underwater Vehicle (UVV). The proposed workflow was validated by performing experiments and collecting real world data in a dam with a length of approximately 150 m and depth around 3 m. The results showed that data collected from the vehicle sensors can be used to create satisfactory 3D dam reconstructions as long as the density of the point cloud is high enough.

Sensors Integration and Applications

Design of a CNN based autonomous in-seat passenger anomaly detection system

Avik Bhatnagar, Pratyush Nandi and Anubhav Mishra (International Institute of Information Technology Bangalore, India); Madhav Rao (International Institute of Information Technology - Bangalore, India)

Physical attacks, abuse, and harassments on the commuters are on rise across the world and detecting distress among passengers is still a techno-social challenge. An autonomous solution to detect passenger anomaly inside the moving vehicle without compromising on the privacy of the commuters is an ideal solution to this problem. Detection of passenger's state in the form of temporal posture of the passenger on a moving vehicle is an apt solution. The passenger state identification followed by a standard evidence capture and assistance system will fulfill all the demands of a safe mobility ecosystem. A proof-of-concept detection system is designed, developed and tested in a real-world scenario. An array of 15 pressure sensitive conductive (PSC) sensors were optimally placed inside a pair of cushions and rested individually on the backrest and the seat of a hired cab. The embedded sensors were interfaced to an edge device which is equipped to run CNN-LSTM hybrid model to identify passenger anomaly state. A dataset consisting of sensory signals for two different states namely - anomaly, and relaxed, on different road and vehicle conditions, using multiple trials from different subjects, was built to develop a robust model. The CNN-LSTM hybrid model running on edge device reported very

high accuracy compared to other models such as SVM, and individual CNN and LSTM models. The CNN-LSTM hybrid model extracts spatio-temporal features to accurately predict the passenger state, which is otherwise a challenging task. A high classification accuracy was reported for the model when applied on unseen dataset which was different from the one used for training the model. A robust CNN-LSTM hybrid model along with a low cost in-seat sensory design which is feasible, and easily scalable, offers a reliable solution, without compromising on the privacy of the commuters. The CNN-LSTM model deployed on an edge device was characterized for a latency of less than 2 seconds for the entire system to detect passenger anomaly state.

Mechanical characterization of a piezoelectric sensor for podiatrist applications

Samia Adrar (IETR Nantes, France)

The analysis of plantar pressures is an integral part of the series examinations carried out by the podiatrist, it allows him to visualize the distribution of the points of support and the movements of the foot during the different phases of walking. The system used for the analysis is a podiatry treadmill composed by piezoelectric sensors which react to the applied pressure. The recorded data (the output voltages of sensors) will be converted into force data for a correct interpretation of the results by medical specialists.

This article presents a part of the development of a podiatry sole based on piezoelectric sensors manufactured in the IETR-Nantes laboratory[1]. The mechanical characterization of an industrial sensor (7BB-35-3L0) from Murata will be presented first to validate the repeatability and the reproducibility of the measurement method, which should allow to define the transfer function relating the output of the sensor to the applied stress. A Shimadzu EZ-X series universal electromechanical test frames are used to apply pressure to the industrial sensor, at the same time as the machine records the force data, a national instrument acquisition card is connected to the sensor to collect his signal. Two methods are tested for the processing of the recorded data, the results obtained make it possible to validate a method which gives a constant coefficient representing the transfer function, thus leading to the final objective which is to characterize the flexible piezoelectric sensors manufactured at the IETR laboratory.

A Deep CNN System for Classification of Emotions Using EEG Signals

Jacqueline Heaton (Queen's University, Canada); Sidney Givigi (Queen's University & Royal Military College of Canada, Canada)

Emotion classification has many applications in human-computer interaction, and is a necessary mode of communication for many different tasks where humans and robots must work together or in close quarters. When working with people who have trouble using verbal communication, or when it is unrealistic to expect verbal communication, robots must still be capable of taking the person's emotions into account, whether through facial cues, body language, or other signals. Electroencephalograms are capable of capturing the signals of the brain, which can be processed and classified using various artificial intelligence architectures. In this paper, a deep convolutional neural network is applied to an emotion classification task, where it successfully learns to identify six second windows as one of four emotions: boredom, relaxation, horror, and amusement. The neural network is applied to 14 individuals and a high accuracy of nearly 100\% is achieved when the test data is chosen randomly from the dataset. A study is performed to find what conditions in the data are necessary for high classification accuracy. The

emotion data was collected from subjects as they played four games of different genres, designed to evoke one emotion out of boredom, relaxation, humor, or fear, as assessed by the professional game critic services.

Leveraging ambient sensing for the estimation of curiosity-driven human crowd

Anirban Das (IIIT Guwahati, India); Kartik Narayan and Suchetana Chakraborty (Indian Institute of Technology Jodhpur, India)

Identification and characterization of human crowd formulation have been a topic of immense interest in recent times due to its applicability in a wide range of smart-city applications covering infrastructure automation to targeted advertising. The core idea is to extract the dynamics and associated behavioural patterns of mass gatherings within an environment through a continuous remote monitoring of the crowd. In general, the existing approaches heavily rely on computer vision and image processing based algorithmic tools and techniques to address this problem or mandate the crowd entities to carry a smartphone with them. However, considering the ubiquitous design goals of futuristic smart applications, camera and smartphone driven active sensing is not suitable to honour users' right to privacy by requiring an active user participation. In this work, we introduce a novel approach towards measuring the spatio-temporal significance of an object in terms of the curious crowd it has attracted over the others. The proposed approach utilizes a set of passive sensors and Wireless signal properties for the necessary estimation. We validate the idea using a room-scale testbed with rigorous experimentation in a real-world scenario. The low cost solution has minimal invasive footprints towards privacy and is capable to reach beyond 90% of accuracy for this measurement.

Gaze Convergence Based Collaborative Performance Prediction in a 3-Member Joint Activity Setting

Rakesh Veerabhadrappa, Asim Bhatti and Imali Hettiarachchi (Deakin University, Australia)

Teams engaged in desktop-based collaborative problem solving has been increasing in recent years. Multi-party joint activities such as computer-supported collaborative working (CSCW) demands intelligible communication for efficient coordination and cooperation. Although, studies have demonstrated a relationship between members' gaze and performance, however, the practicality of application in larger groups and intelligent predictive modelling has slowly progressed. One common constraint observed in literature is that much of the studies use dyadic team setting, and when larger groups are considered studies have resorted to a laborious examination of videos. Further, in the context of prediction, regression and binary classification are observed in the literature. Thus, indicating that the selection of appropriate team members gaze features can aid in the development of predictive models. This study aims to advance gaze-based collaborative research by overcoming some of the drawbacks. In this light, a desktop-based 3-member collaborative activity is adopted in the study to facilitate our investigations. Linear statistics were explored to observe gaze convergence and observed a significant correlation with task performance. The measures were used to model a multivariate regression equation and a neural network, and the mean absolute errors of both models were compared. The comparison revealed promising results suggesting the employment of team members' gaze behaviour for objective assessment and prediction of collaborative performance.

Using Eye-tracking To Investigate The Effect of Gaze Co-occurrence and Distribution on Collaborative Performance

Rakesh Veerabhadrappa, Imali Hettiarachchi and Asim Bhatti (Deakin University, Australia)

How important is it to look together compared to looking apart? In collaborative problem-solving tasks, there is a mixed opinion about the relationship between gaze behaviors and task performance. In this light, studies exploring gaze behaviors in socio-dyadic contexts report a positive effect on performance. Contrastingly, work teams and tactical scenarios with complex problems have reported a negative effect on performance. Solely, focusing on group problem-solving in natural settings, this study investigates the collective effects of gaze co-occurring and distribution of gaze on performance. A 3-member cooperative task resembling a computer-supported collaborative working environment is chosen for this investigation. Seventeen teams participated in this study, and their eye movements were captured using eye-tracking devices. Methods to quantify gaze behaviors co-occurrence and distribution for 3-member teams is introduced. Pearson's correlation coefficient was used to analyze the relationships. The study presents a multivariate regression equation to achieve a composite index that combines measures from both gaze co-occurring and distribution. Results demonstrated both gaze behaviors and the composite index shared a significant relationship with performance.

Design and Analysis of a Low-Cost Weather Monitoring System based on Standard IoT Data Protocols

Marcelo Augusto Sudo (Federal University of São Paulo, Brazil); Sergio Ronaldo Barros dos Santos and André Marcorin de Oliveira (Federal University of Sao Paulo, Brazil); Sidney Givigi (Queen's University & Royal Military College of Canada, Canada)

The world is converting to the use of 5G, and it will certainly boost IoT services, devices and business in general. One vital characteristic of 5G is the velocity of data transference, which reflects on performance matters. So this paper presents an analysis of performance of some IoT Protocols, such as MQTT, CoAP and HTTP REST, in a case study of a weather monitoring system built with a NodeMCU ESP8266 linked to an Arduino UNO. The meteorological station reads temperature and humidity (DHT11), atmospheric pressure and altitude (BMP180), luminosity (LDR), toxic gases (MQ135), and presence of flammable and smoke (MQ2) with several sensors. On the other side of the link, there is a Java application which reads the measures through the mentioned protocols stressing them by varying the message length and the time interval between requests. All data are stored in a MySQL database which may be available to any kind of user interface that needs to present them, which is not tackled in this study. The results showed that MQTT is the most appropriate for this application, as it transmits the messages in shorter time and with higher reliability of completeness of the information sent, regardless of their size. On the other hand, CoAP is the less reliable for this application being the one which missed almost half of the messages for a very short time interval.

Simulation and Analysis

Evaluation of Failure Analysis of IoT Applications Using Edge-Cloud Architecture

Mohammad Jassas (University of Ontario Institute of Technology, Canada); Qusay Mahmoud (Ontario Tech University, Canada)

The most important features of the Internet of Things (IoT) application architecture are connectivity, detection, scalability, intelligence and integration. IoT devices should be developed and installed to be scaled up or down, depending on the business and application requirements. Cloud computing has faced various challenges due to its rapid expansion. Because of its remote geographical location, cloud computing cannot respond to the growing number of IoT devices and the data they generate, and maintain their quality-of-service criteria, such as low latency. Edge computing models are urgently needed to develop the Internet of Things (IoT) applications. This paper examines the effects of the combination of IoT, Cloud and Edge computing for failure analysis and prediction. Furthermore, based on the Edge-Cloud architecture, we offer an architecture for a highly reliable and available IoT application that can support the new paradigm of IoT applications. Our proposed model can reduce the number of failed tasks for Cloud-IoT applications. We have also examined how many tasks fail when different architectures are used. The evaluation results show that failed tasks and CPU usage have decreased in the use of the "Edge and Cloud" architecture. In addition, using "Edge and Cloud" architecture can also control network traffic compared to other architectures.

Socio-Technical Systems

Managing Pandemic Resilience with Other Cascading Disruptions of a Socio-Technical System

Davis C Loose, Timothy L Eddy, Jr and Thomas Polmateer (University of Virginia, USA); Mark C. Manasco (Commonwealth Center for Advanced Logistics Systems, USA); Negin Moghadasi and James H. Lambert (University of Virginia, USA)

The COVID-19 pandemic spurred the development of methodologies to assess risk to economic development plans. To increase local recovery efforts, the federal government provides funding for regional economic development. Funds are allocated based on immediate needs as well as growth potential. This work advances the risk register methodology to prioritize infrastructure initiatives while considering the influence of exogenous scenarios on initiative priorities given the impact of COVID-19. The risk register identifies performance criteria which measure performance -- for example, providing funding to restaurants to increase outdoor seating and create new jobs. Next, the register identifies disruptive events and groups these events into scenarios. There are now two sets of data: the initiatives under consideration, and a set of disruptive scenarios, including a baseline. The register evaluates the impact of each scenario on each initiative. For each scenario, the initiative with greatest impact on performance criteria is ranked first, and so on for the remaining scenarios. These rankings mathematically capture the influence of each scenario on the priority of each initiative. The risk register mathematically quantifies the disruptiveness of each scenario, allowing the comparison of different disruptive events. This information can help determine how to allocate resources to improve system

resilience. The risk register methodology is applied to a socio-technical system of systems. This work advances methods outlined in the Systems Engineering Body of Knowledge, specifically the System of Systems knowledge area.

System-of-systems optimization for healthcare: a use-case in radiation oncology

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Many healthcare applications, such as radiation oncology (RO), represent a complex system of systems (SoS). However, there are minimal systems modeling examples seen in literature that demonstrate applicability of this methodology. In this work, we apply a SoS architecture modeling approach to optimize a RO department's technology, staffing, and task operations.

The key performance attributes (KPAs) of accuracy, safety, affordability, timeliness, and robustness were selected to drive the success of effectively treating a cancer patient. Technology choices such as commercial vs. in-house software or single-vendor comprehensive vs. multi-vendor specialization software products represent some of the technological systems in an RO department. Varying degrees on specialization of staffing models for each set of employees, such as radiation oncologists and medical physicists, within RO were optimized. These varying systems were inputted into a fuzzy inference system (FIS). Finally, how and when tasks were performed were added as "task systems" which would augment or detract from varying KPAs. These "task systems" were also included in the FIS as stand-alone systems with no interfaces to any other system. A simple genetic algorithm (GA) was used to optimize the overall SoS architecture using a fitness function derived from the KPA-defining equations. Finally, we compared our best overall SoS meta-architecture (SoS-MA) against an existing RO department.

Using a SoS-MA approach to a radiation oncology department, we were able to successfully represent and optimize a healthcare SoS. The FIS approach allows end-users to explore the uncertainty or fuzziness of how safe or accurate one approach of staffing or technology is over another approach is since these relationships are not generally well-defined. Our approach also optimizes how tasks are performed within the SoS since that will affect how the overall meta-architecture. When comparing against an existing RO department, our SoS-MA differs by suggesting having both a single-vendor comprehensive technology and multi-vendor specialization tools instead of the existing RO department's single-vendor comprehensive technology. Additionally, our SoS-MA suggests parallel task operations whereas the existing RO department accomplishes tasks in a sequential manner. This change in operations would be a large shift in RO practices but would greatly increase the timeliness and robustness of care.

In conclusion, we've applied a SoS-MA approach to a radiation oncology department that can be used to aid end-users in design and operations of their department. If successfully applied in practicality, the SoS-MA approach could help drive down healthcare costs and increase both efficiency and safety.

CVSS-based Vulnerability and Risk Assessment for High Performance Computing Networks

Jayanta Debnath (University of Toledo, USA); Derock Xie (Kentucky Country Day School, USA)

Common Vulnerability Scoring System (CVSS) is intended to capture the key characteristics of a vulnerability and correspondingly produce a numerical score to indicate the severity of a given vulnerability in a system. Important efforts are conducted for building a CVSS stochastic model in order to provide a high-level risk assessment to better support cybersecurity decision-making. However, these efforts consider nothing regarding HPC (High-Performance Computing) networks using a Science Demilitary Zone (DMZ) architecture that has special design principles to facilitate data transition, analysis, and store through in a broadband backbone. In this paper, an HPCvul (CVSS-based vulnerability and risk assessment) approach is proposed for HPC networks in order to provide an understanding of the ongoing awareness of the HPC security situation under a dynamic cybersecurity environment. For such a purpose, HPCvul advocates the standardization of the collected security-related data from the network to achieve data portability. More importantly, HPCvul develops a Bayesian attack graph to model the likelihood of successful exploitation of a vulnerability in an HPC network. It is able to merge multiple attack graphs from different HPC subnets to yield a full picture of a large HPC network. Vulnerability metrics are developed to evaluate the security risk given an HPC networking component. Substantial results are presented in this work to demonstrate HPCvul design and its performance.

Space and Communications Systems

Cislunar Systems Architectures Survey Paper

Laura Duffy and Jim Adams (Colorado State University, USA)

The next space race has begun. Plans are well underway to establish architectures in cislunar space. This paper provides a summary of research conducted on cislunar space architectures, including primary missions and supporting functions. Planned primary missions can be broadly categorized as science, commercial, and defense missions. Supporting functions are broadly categorized as transportation, communication, navigation, domain awareness, service, energy, shelter, and control. Potential solutions and identified gaps for each mission and supporting function is offered in this paper. Transportation includes the subfunctions of launch, inter-orbital transportation, human transportation, and staging platforms. Transportation architectures are in work by the United Launch Alliance (ULA) and NASA through the Space Launch System (SLS), Orion capsule, and Gateway staging platform.

The communication supporting function includes dedicated communication between the Earth and Moon, including the far side of the Moon. Communication architectures in development include SDA's architecture in low Earth orbit and NASA's architecture of communication nodes around the Moon called LunaNet. The navigation function includes the subfunctions of dedicated navigation and tracking. NASA's LunaNet architecture also serves the navigation function, but a dedicated tracking network has not been identified by any agency. The domain awareness function includes subfunctions of surveillance and collision avoidance. One identified space domain awareness program is the Cislunar Highway Patrol System (CHPS), funded by

the Air Force Research Laboratory (AFRL), to conduct research and development in this arena. The service function includes subfunctions of on-orbit servicing, manufacturing in space, on-site extraction, and materials processing. Service functions will likely be a long-term, commerce endeavor, but no architectures are in development. The energy function is tightly coupled with the service function, including subfunctions of energy collection, energy distribution, fuel storage, on-site extraction, and materials processing. Energy will also be a profitable endeavor for commerce missions, but no architecture is currently in development. The shelter function has the subfunction of human habitation. NASA's Habitation and Logistics Outpost (HALO) is an identified program to provide shelter on the Gateway. The control function includes the subfunctions of status, commanding, and fault detection/recovery. AFRL is initiating programs to research the unique issues that arise when conducting control in cislunar space. Ample research has been conducted for each primary mission and supporting function. However, a comprehensive cislunar space architecture is lacking.

System Architecture

COGENT: A Concurrent Engineering and Generative Engineering Tooling Platform

Christopher O'Hara (Eindhoven University of Technology, The Netherlands); Mark van den Brand (Eindhoven University of Technology, Netherlands, The Netherlands); Jonathan Menu (Siemens, Belgium)

System architecture design is a complex and complicated process. Systems, subsystems, and components must undergo a strict evaluation process detailing trade-offs, risks, benefits, and feasibility at the fringes of what is technologically possible. Poor architecture design leads to poor product performance, wasted resources, and in worst-case scenarios-fatalities caused by mission/product failure. Two upcoming domains seek to improve the generation, evaluation, and selection of system architecture configurations. These domains are generative engineering and concurrent engineering. Generative engineering allows for the automatic generation and evaluation of thousands of architecture configurations. Concurrent engineering is a methodology of subsystem design teams working collaboratively and simultaneously to create and select system architecture configurations. However, what had yet to be established was the value of combining the two domains. We sought to combine generative engineering and concurrent engineering to identify this value by creating the Concurrent Generative Engineering Tooling (COGENT) platform. COGENT is a plugin solution architecture that enables cross-functional teams in automated system architecture generation in concurrent design facilities. A conceptual FireSat case study was explored, demonstrating COGENT capabilities such as enabling concurrent users, synchronized tool usage, centralized object storage, and connectivity to third-

party software and/or user-defined features for space systems. COGENT is modular, extensible, and easy to integrate into any system development lifecycle. With COGENT, system designers can focus on their primary concerns, goals, and constraints. Using COGENT will allow system engineers, system architects, and subsystem designers to identify optimal system architecture configurations at a fraction of the time and cost.

A Container-Based Architecture to Build and Deploy Applications within a Social Network

Michael Lescisin and Qusay Mahmoud (Ontario Tech University, Canada)

The paradigm of container-based architecture has revolutionized web application development by, increasing service reusability, decreasing service deployment times, facilitating the construction of distributed systems, and providing strong guarantees of resource isolation without the overhead of full virtual machines. These advantages of container-based architecture have caused it to be embraced by many web application developers. In this paper, we focus on end-users as the target audience of container-based architecture and present SocialSDN as a tool to facilitate the design and deployment of web applications to be used within the context of a social network. We present several use cases and compare to existing solutions.

Systems Engineering

Combating Advanced Persistent Threats for Imminent Low Earth Orbit Cognitive Communications Systems

Suzanna J LaMar (Colorado State University, USA); Lisa Happel and Jordan J Gosselin (Northrop Grumman Corporation, USA); Anura P Jayasumana (Colorado State University, USA)

With the proliferation of Low Earth Orbit (LEO) spacecraft constellations, comes the rise of space-based wireless cognitive communications systems (CCS) and the need to safeguard and protect data against potential hostiles to maintain widespread communications for enabling science, military and commercial services. For example, known adversaries are using advanced persistent threats (APT) or highly progressive intrusion mechanisms to target high priority wireless space communication systems. Specialized threats continue to evolve with the advent of machine learning and artificial intelligence, where computer systems inherently can identify system vulnerabilities expeditiously over naive human threat actors due to increased processing resources and unbiased pattern recognition. This paper presents a disruptive abuse case for an APT-attack on such a CCS, and describes a trade-off analysis that was performed to evaluate a variety of machine learning techniques that could aid in the rapid detection and mitigation of an APT-attack. The trade results indicate that with the employment of neural networks, the CCS's resiliency would increase its operational functionality, and therefore, on-demand communication services reliability would increase. Further, modelling, simulation, and analysis (MS&A) was achieved using the Knowledge Discovery and Data Mining (KDD) Cup 1999 data set as a means to validate a subset of the trade study results against Training Time and Number of

Parameters selection criteria. Training and cross-validation learning curves were computed to model the learning performance over time to yield a reasonable conclusion about the application of neural networks.

Intention-based engineering for process plants

Artan Markaj (Helmut Schmidt University Hamburg, Germany); Nicolai Schoch, Katharina Stark and Mario Hoernicke (ABB Corporate Research Center Germany, Germany); Alexander Fay (Helmut-Schmidt-Universität, Germany)

The engineering of process plants in the chemical and pharmaceutical industry is a highly complex process where different disciplines work together from the recipe of the (chemical) substance that shall be produced, through process and automation engineering to commissioning and operation of the process plant. Especially the early phases of engineering are essential due to the various, indicatory decisions taken. These decisions are often based on the engineers' intentions during the engineering process. This paper presents a systematic engineering approach for process plants based on the engineers' intentions - the so-called intention-based engineering. The main idea of the intention-based engineering approach is to use the engineers' intention as the basis for the system design to support the early phases of engineering. By assigning meaning to decisions and system elements, the various disciplines involved in the engineering process can comprehend the decisions made and adjust their own ones based on the previous decisions. The approach consists of three steps, starting from the formulation of intentions by using a controlled language, to the modelling of intentions by adding additional information such as dependencies, up to the design with intentions. The first and second step derive the intention model which represents the core of the intention-based engineering approach, while the last step focuses on the integration and usage of the intention model in the process plant engineering steps. Furthermore, requirements for the engineering approach are formulated before introducing the concept of intention-based engineering. The approach is evaluated using a 3-phase separator.

A multilevel Crews Patrolling Framework for Distribution System Recovering

Matheus de Souza Sant'Anna Fogliatto, Luiz Desuó Neto and Henrique Caetano (Universidade de São Paulo, Brazil); Rodrigo Fanucchi (COPEL & University of São Paulo, Brazil); Carlos Maciel (USP, Brazil)

Diverse socio-economic impacts derive from power outages in distribution networks caused by faults. Estimating fault location comprises crews' dispatch for patrolling the power lines in the outage area. Previous studies do not consider road network damage on patrolling procedures. Not taking into account the interdependency between the power distribution system and road network may underestimate the importance of the consequences. Additionally, the lion's share of the literature neglects the crews' pre-positioning, usually starting from depots, which does not reflect the truth. Typically, crews are performing in-field operations when an outage occurs. In this manner, this work proposes a bilevel optimization for patrolling procedures and suggests pre-positioning regions for in-field crews based on community detection. In addition, Monte Carlo simulations followed by statistical models verify the pre-positioning and the bilevel optimization improvements on reliability indices.

The framework proposed in this work seeks to interconnect several factors that end up influencing the service provided in these systems, such as failure history, characteristics and

location of faults, and atmospheric factors, such as precipitation level, that can aggravate the occurrence of such events for a specific period, were considered. On the other hand, it seeks to optimize the issue of number and location of maintenance teams, being able to prepare for adverse events through elements such as weather forecast.

Closed Systems Paradigm for Intelligent Systems

Niloofar Shadab and Tyler Cody (Virginia Tech, USA); Alejandro Salado (The University of Arizona, USA); Peter Beling (University of Virginia, USA)

Intelligent systems ought to be distinguished as a special type of system. While some adopt this view informally, in practice, systems engineering methods for intelligent systems are still centered around traditional systems engineering notions of engineering by aggregation and decomposition of components. We posit that this traditional approach follows from holding a notion of open systems as the fundamental precept and that engineering intelligent systems, in contrast, requires an approach that holds notions of closed systems as fundamental precepts. We take a systems theoretic approach to defining open and closed system phenomena and their relation to engineering intelligence. We aim to institute a closed-system approach to characterize intelligence as a property of the system's relation to its context by emboldening the shift from the concepts behind the requirement-functions relationships in systems engineering and aligning them with the presented closed systems view. We propose the concept of variety; particularly the law of requisite variety to enable a closed view paradigm in engineering intelligent systems. We discuss how open and closed view approaches to engineering intelligent systems address variety differently, as well as the implications of this difference on engineering practices. Then, we provide a research roadmap for systems engineers to align their practices with the closed system view.

Natural Language Processing to Extract Contextual Structure from Requirements

Maximilian Vierlboeck, Daniel Dunbar and Roshanak Rose Nilchiani (Stevens Institute of Technology, USA)

The automatic extraction of structure from text can be difficult for machines. Yet, the elicitation of this information can provide many benefits and opportunities for various applications. Such benefits have been identified amongst others for the area of Requirements Engineering. By assessing the Natural Language Processing for Requirement Engineering status quo and literature, a necessity for an automatic and universal approach to elicit structure from requirement and specification documents was identified. This paper outlines the first steps and results towards a modularized approach that splits the core algorithm from the text corpus as an input and underlying rule/knowledge base. This separation of functions allows for individual modification of the included parts and eases or potentially removes restrictions as well as limitations, such as input rules or the necessity for human supervision. Furthermore, contextual information and links via ontology inference can be considered that are not explicit on a textual level. The initial results of the approach show the successful extraction of structural information from requirement text, which was validated by comparing the results to human interpretations for small and public sample sets. In addition, the contextual consideration and inference via ontologies is described conceptually. At the current stage, limitations still exist regarding scalability and handling of text ambiguities, but solutions for these caveats have been developed and are being tested. Overall, the approach and results presented will be integrated and are part of a novel requirement complexity assessment framework.

Understanding Risks in Smart City Projects

Nader Mohamed (California University of Pennsylvania & Middleware Technologies Lab., USA); Jameela Al-Jaroodi (6001 University Blvd., USA); Imad Jawhar (Al Maaref University, Lebanon); Nader Kesserwan (Robert Morris University & School of Engineering, Mathematics and Science, USA)

Many cities worldwide have moved or are considering moving towards becoming smart cities for better services and quality of life for the residents and visitors; optimized resource utilization; improved environmental protection; improved infrastructure operations and maintenance; and strong safety and security measures. This trend will start many smart city systems projects worldwide. Nevertheless, many risks could face these projects leading to problems and making it hard to meet their defined objectives within the defined scopes, times, costs, and quality. These risks could result in delaying or even terminating some projects. This paper investigates the risks in smart city projects and discusses some strategies to deal with them. These risks can be categorized as business, technical, organizational, project management, and political risks.

Systems Engineering Education & Theory

Multidisciplinary Systems Engineering Senior Design Projects Pilot Program at Bourns College of Engineering University of California Riverside

Hossny Elsherief (University of Riverside, USA)

This paper describes a pilot research program to evaluate the application of Systems Engineering in senior design projects, at the Electrical and Computer Engineering Department, University of California Riverside. Integrating Systems Engineering processes into senior design projects is an effective approach to include convergence in the undergraduate engineering education curriculum. The objectives of the pilot program are to assess its design approach in terms of the implementation structure and assess students' feedback. Students participating in the pilot program executed their projects in a way to emulate a typical Systems Engineering industrial development process. At the end of the pilot program students were asked to assess the effectiveness and the value of integrating Systems Engineering into their senior design projects' execution. Students feedback indicated that the pilot program contributed to increased awareness and interest in Systems Engineering careers. Students said that Systems Engineering was very helpful in executing their senior design projects and gave them a valuable "System Thinking" experience of an industrial product development process. Our pilot program assessment's results showed that students completed their projects successfully on-time and their participation in the program contributed to significant improvement in their team work, technical presentation and project management skills. Systems Engineering senior design projects align well with the ABET accreditation process. Academic institutions can use the

senior project data to help them establish the required direct assessment measures of the attainment of some of the ABET student outcomes.

Potentials of Design Thinking for knowledge transfer of Model-Based Systems Engineering

Marvin M Manoury (Fraunhofer IPK, Germany); Thomas Zimmermann (Fraunhofer, Germany); Toni Horländer (Unity AG, Germany)

Industrial products are becoming increasingly complex due to the use and development of mechatronic systems. This increasing complexity is addressed by virtual representations of the systems in the form of interdisciplinary models. Model-Based Systems Engineering (MBSE) supports product development from the early development phase through validation, verification and integration up to later life cycle phases of the product by means of system modeling. Typical drivers for innovations in the industrial environment are business viability, technology driven feasibility and human driven desirability. While business viability and feasibility are considered in most product development processes and innovation driven projects, the human factor is often neglected in this context. This is addressed by a MBSE Capability and Maturation Matrix (CMM), which consists of capabilities for the acquisition and mastering of the MBSE competencies. The authors have considered Design Thinking as a feasible approach to transfer MBSE knowledge and thus support this acquisition MBSE competencies. This publication shall present the first findings on the application of Design Thinking for the creation of a user-centered MBSE introduction event. This event shall be used in further iterative steps to teach non-experts in the MBSE field the required competencies for their work and thus support the CMM development capability.

Identification of stakeholder-specific Systems Engineering competencies for industry

Ulf Koenemann (Fraunhofer IEM, Germany); Roman Dumitrescu and Harald Anacker (Fraunhofer-Einrichtung für Entwurfstechnik Mechatronik IEM, Germany); Daria Wilke (Fraunhofer IEM, Germany)

Product complexity is increasing due to various drivers, such as digitalization. Products with new technologies are often referred to as Advanced Systems. Due to increasing product complexity, the associated product development is also becoming increasingly complex. Systems Engineering (SE) is a proven approach to meet these challenges. Various studies have shown that introducing Systems Engineering company-wide is a major challenge for enterprises. To address those challenges a holistic approach is recommended, which takes into account the aspects of "human, technology and organization". This paper provides insight into the initial research findings within the research project SE4OWL, specifically considering the individuals' acceptance as part of the aspect "human". The qualification of employees towards the topic of SE has a very decisive role for the company-wide stabilization and acceptance of SE. In order to gain the acceptance for SE among the employees, the individual needs must be addressed within those qualifications. Therefore, for each individual stakeholder the needed competencies shall be identified to derive qualification measures.

This paper presents a concept to identify Systems Engineering (SE) competencies for different stakeholder groups within a company. An overview of the current state of research and the challenges of implementing Systems Engineering in industry is given. Based on this state of the art a solution concept will be presented.

Initial Development of a Roadmap for Digital Engineering Simulations Curriculum

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This paper describes the context and approach for a research task developing a digital engineering simulation environment. The purpose of the simulation environment is to create a learning platform that can be used to help students attain higher levels of proficiency in critical digital engineering skills beyond what is possible in a traditional classroom setting. This task leverages the existing literature community and builds on the extensive digital engineering research portfolio of the Systems Engineering Research Center (SERC). The initial research results are described within. This research is funded by the Defense Acquisition University (DAU). The goals for this research are the development of DE simulations for teaching DAU students and the development of an accompanying set of teachable modules that will significantly enhance the capabilities of DAU students who complete the DAU training in the evaluation and acquisition of complex systems from a broad range of domains including cyber resilience, AI systems, and weapon systems. The architecture of the digital engineering simulation is developed in a manner that allows adaptability and extensibility into other disciplinary areas beyond the engineering, acquisition, and sustainment areas. In addition, the team aims to contribute to the body of knowledge on digital engineering and systems engineering education through this research project.

Systems Integration and Verification

Analyzing and Predicting Overall Equipment Effectiveness in Manufacturing Industries using Machine Learning

Bruno Vilela Souza, Sergio Ronaldo Barros dos Santos and André Marcorin de Oliveira (Federal University of Sao Paulo, Brazil); Sidney Givigi (Queen's University & Royal Military College of Canada, Canada)

This paper investigates the use of machine learning algorithms to derive an approximated metric model for predicting the Overall Equipment Effectiveness (OEE) from an industrial process. Analyzing this information, it is possible to ensure better understanding of the business and stimulating the search for improvements of the productive efficiency in industries. In this context, our objective is to explore and apply different ML techniques (supervised and unsupervised learning algorithms) to derive an approximated metric for estimating the overall efficiency in a production line using historical data (dataset) obtained from actual machines in a factory. By using the manufacturing data of a product and specific learning algorithms, a prediction model is created to identify the ideal OEE metric, indicating that the equipment will be used according to its capacity and productive efficiency. Thus, we are able to predict the OEE of a given machine, and to analyze the behavior obtained in order to improve production. From the learning OEE metric, it is possible to analyze the equipment behavior and verify the existence of some patterns which could be used to propose improvements in the manufacturing process. Experimental results have demonstrated the feasibility and evaluation of the proposed models for verifying the efficiency of the industrial plant for different business standards.

Transportation Systems

Flexible Model Exchange in Modelling Smart Mobility by Using Domain Ontologies

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The development of smart mobility calls for the simultaneous consideration of multiple stakeholders' perspectives while considering local circumstances. The analysis in simulation allows the efficient comparison of different scenarios and options to support the decision-making process. As diverse aspects call for different simulative implementations, the use of numerous modelling approaches reveals unsolved challenges in the integration process towards a comprehensive and consistent simulation. Taking the example of planning public charging infrastructure, three stakeholder groups as different component models with their interdependencies form the co-simulation framework. Facing the high adaptability required, the exchange of models and their integration come in focus, aiming for a mostly automated procedure to integrate a new model within an existing simulation framework. Domain ontologies enable the comparison of incorporated parameters and their transformation. Meta data allows to highly automate this process. The challenges to overcome are elaborated and the process of exchanging a component model is introduced. Thereby, this paper contributes to fill the gap between the standardization of model interfaces and the functionalities of existing master algorithm for simulation execution in the mobility domain. The application of the here-presented methodology facilitates and supports the decision-making for future mobility in general. It enables an existing simulation framework's adoption to spatial particularities and changes over time.

Why System Requirements Must Influence the Selection of Causal Models to Address Congestion in Freight Logistics

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There is urgent need to identify goods which may be diverted to an alternative mode of freight movement due to the disruptions to priorities and decisions of logistics entities by Covid-19, container shortages, labor shortages, etc. Here diversion refers to the shift of goods in the logistics network that are typically moved via one freight mode - such as rail, highway, or air - to another mode. There has been significant effort to model this behavior for purposes of infrastructure planning by both national and regional transportation agencies. In the United States this has culminated in a gold standard behavioral/agent-based model supported by the Federal Highway Administration (FHWA) and implemented by state transportation agencies. This model is well established and demonstrated to successfully predict the diversion of goods from one mode to another in response to changes in the freight network. However, this model is limited to consideration of the requirements state or national transportation agencies value. As a result, the model requires large teams, years of work, and millions of dollars in funding. This scale is not acceptable for modeling of transient events such as container shortages which would dissipate before model completion. This work advances a novel approach to model this behavior that is sensitive to the requirements of a diverse set of stakeholders and conditions.

System Modeling and Performance Evaluation of Predictive QoS for Future Tele-Operated Driving

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Future tele-operated driving use-cases place challenging demands on existing mobile communication networks. New remote control and platooning services will emerge and pose high data rate and latency constraints. One key enabler for these applications is the newly available 5th Generation of Mobile Communication Networks (5G) New Radio (NR) network promising higher bandwidths and lower latency than its predecessors. However, several challenges in the implementation process of tele-operated driving have not yet been overcome. In addition to that, public 5G networks do not consistently deliver and do not guarantee the required data rates and latency of Tele-operated Driving (ToD).

In this paper, we discuss several aspects and requirements of tele-operated driving. ToD is regarded as a complex system consisting of multiple research areas. One key aspect of ToD is providing the required data rate for teleoperation by the mobile network. An in-advance prediction method of the end-to-end data rate based on so-called Radio Environmental Maps (REMs) is discussed. Furthermore, a novel approach improving the prediction accuracy is introduced and it features individually optimized REM layers.

Finally, we analyze the implementation of tele-operated driving applications on a scaled vehicular platform combined with a cyber-physical test environment consisting of real and virtual objects. This approach enables large-scale testing of remote operation and autonomous applications.

No Topic

Multi-Input Non-Deterministic State-Machines (MINDS) to Support Aerospace Systems Engineering Simulation and Analysis

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As new commercial and military aerospace systems evolve, end-users face significant systems challenges that require solutions beyond prior approaches from traditional aerospace systems engineering. For example, military commanders recognize that in order to confront threats from high-tech adversaries, an advanced system of systems (SoS) is required to coordinate combat across multiple battlefield domains: land, sea, air, space, and cyberspace. Some refer to such a battlespace environment as Joint All Domain Command and Control (JADC2). Many disparate criteria from a variety of systems fulfill portions of this challenge. However, none solves the overall JADC2 problem. Rather than continuing the practice of developing new systems with new criteria and capabilities for each new challenge and abandoning their significant prior investments, end-users seek a solution that will permit them to merge the best criteria and capabilities from their existing systems. To do so with confidence, these end-users need a method to quantify how to combine appropriate systems, criteria, and capabilities relative to the given customer need (e.g., requirements, scenario, Concept of Operation) in order to achieve optimum mission performance. This paper describes a new analytic approach to assess the relevance of disparate systems and their respective criteria and capabilities with respect to a given set of customer requirements for a given mission, thereby identifying the subset of criteria and capabilities relevant to that mission and quantifying the best available SoS to meet that

need. To do so, we present a new method for Multi-Input Non-Deterministic State-machines (MINDS).

The MINDS approach begins with the application of a Markov Decision Processes (MDP) to account for all possible combinations of criteria and capabilities. This approach allows MINDS to represent the mission as set of composite MDPs that create a non-deterministic state machine in which criteria and capabilities are linked through probabilistic state transitions. The terminal states for each criterion provide the best available combination of capabilities to achieve that criterion, and the overall terminal state for the mission represents the best available combination of criteria and capabilities to achieve the overall mission objectives.

The objective of this approach is to achieve the mission terminal state with the fewest states and therefore the fewest state transitions. This translates to the fewest capability combinations, and therefore the least amount of work and fewest steps to reach a conclusion on the best capability combinations to satisfy mission success. A new concept introduced here is the idea of a hierarchy where MINDS can be applied at the mission level, the criteria level and the capability level. At each of these levels, MINDS implements a merger function that provides an analytical basis for merging capabilities and progressing towards the terminal state and mission success. MINDS also applies a threshold function that determines whether the path is operational and can continue towards the terminal state or non-operational and return to the initial state.

The MINDS MDP approach was reduced to practice for a notional Department of Defense mission use case. In doing so, we applied the merger and threshold functions to reduce the number of possible criteria/capabilities combinations.