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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 2021, scheduled to be held March 22-25, 2021 in Vancouver, Canada has been cancelled. IEEE SYSCON 2021 will now be held as a virtual conference, to be held April 15 – May 15, 2021. 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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Autonomous Systems

Safety Assurance for Autonomous Vehicles - A first look at UL 4600
Simon Diemert and Laurent Fabre (Critical Systems Labs Inc., Canada)

Establishing that AI-centric autonomous vehicles are safe continues to be a challenge in both industry and academia. Existing industry system safety standards and engineering techniques, such as those recommended by ISO 26262 (Functional Safety for Road vehicles), are not adequate to assure the safe operation of these new technologies. "UL 4600 - Standard for Evaluation of Autonomous Products" is a new standard that attempts to bridge this gap with a focus on safety assessment for autonomous vehicle systems. UL 4600 establishes the minimum criteria for safety assurance cases that argue the safety of an autonomous vehicle system. Safety assurance cases are structured arguments comprised of claims and evidence that demonstrate that the risk associated with an engineered system is acceptable for the intended application. Safety cases are especially useful for establishing the safety of systems that rely on new technologies where standard engineering techniques might be insufficient and are therefore well suited as a tool for demonstrating the safety of autonomous vehicles. This paper provides a first look at UL 4600 from a practitioner's perspective, including thoughtful critique, and presents a worked example demonstrating how to apply guidance from UL 4600 to a safety assurance case for a fictitious autonomous ground-vehicle.

Autonomous and driver assistance systems are increasingly prevalent in the automotive market. The dominant functional safety standard in the automotive domain is "ISO 26262 - Road Vehicles - Functional Safety" [1]. While ISO 26262 remains an important part of the functional safety framework for the automotive industry, is focused primarily on the mitigation of faults and failures, i.e., deviations from the intended function of a component. While the ISO/PAS 21448 industrial standard (still under development) has been created to address the safety of the intended function (SOTIF) and contains guidance about the development of autonomous systems, it does not explicitly consider the content of a safety case for an autonomous vehicle [2]. Moreover, while ISO 26262 does require that manufacturers prepare a safety case, minimal guidance is provided about the content of that safety case and how it should be evaluated for completeness/correctness. UL 4600 was published in mid-2020 and fills this gap by providing an extensive set of criteria evaluation criteria for safety cases for autonomous systems [3]. UL 4600 does not prescribe a specific safety argumentation technique and therefore does not contain any concrete examples of how to integrate its guidance into a real-world safety case. Since the UL 4600 is structured as a set of "prompts" (intended to spur thinking about particular safety-related scenarios), it naturally fits with the foundational principles of the Eliminative Argumentation (EA) safety case method [4, 5]. Therefore, in addition to a thoughtful review and critique of UL 4600's guidance, this paper applies the guidance to a fictitious autonomous ground-vehicle with the intent of providing assurance case practitioners an example of its use.

The figures below show a subset of a safety assurance case for a fictious Unmanned Ground Vehicle (UGV) that operates exclusive on highways for autonomous snow removal. The figures focus on a sub-argument related to the adequacy of the object detection functions of the UGV's autonomous control software. The EA technique is used to include the guidance from UL 4600 as argument "defeaters" (octagons with red borders).

Development of a low-cost avionics platform for small-scale model airplanes
Matheus Dias Maciel (ITA - Technological Institute of Aeronautics, Brazil)

In the last few years, the usage of UAVs (Unmanned aerial vehicles) has been increasing quickly and its usage in research has also risen. In this context, the use of small-scale aircraft to investigate new approaches and concepts in the field of aircraft systems is a popular technique used by engineers in the field. In research institutes, several avionics platforms are utilized on model aircraft for flight tests with scientific objectives. However, the avionics platforms employed in these model airplanes are very costly. Therefore, using them in highrisk flight tests, such as the airplane's first flight tests or tests with new flight control techniques, should be avoided. From this conjunction, this research project aims at developing a low-cost avionics platform capable of operating different types of small-scale model aircraft for scientific flight tests. The Pixhawk was chosen as the main hardware of the platform due to its extensive use in the development of drone and model aircraft projects. One of the many requirements of this work was to aim at making the development of new controllers for the platforms accessible for all engineers working at any research institute, which is the reason for the use of MATLAB/Simulink embedded systems tools to generate code for the platform.

Experimental Validation of a Steering Control System using an Adaptive Fuzzy Controller and Computer Vision
Thiago Sato, Sergio Ronaldo Barros dos Santos and André Marcorin de Oliveira (Federal University of Sao Paulo, Brazil); Fábio A. M. Cappabianco (Federal University of São Paulo & Universidade Federal de Sao Paulo, Brazil)

This paper proposes an adaptive steering control strategy for self-driving cars based on a Fuzzy Expert System and Reinforcement Learning. Our objective consists in deriving an appropriate control law directly from a real vehicle that allows it to navigate on several types of lanes, by controlling the position in relation to the center of the tracks and also the translation speed of the vehicle. Using an on-line Reinforcement Learning approach, the Fuzzy expert controller is derived considering the coupling and non-linearity of the model on straight and winding tracks. To do this, an embedded camera captures the images and sends them to the computer vision algorithm responsible for performing tracks detection and recognition. From that, the control references which indicate the navigation path and direction on the lane are calculated. The main contribution of this work is to apply an online reinforcement learning approach to tune and optimize the fuzzy steering controller while the vehicle navigates through different routes. Using a real vehicle equipped with an embedded computer and also the implemented web user interface, the learning evolution of the adaptive fuzzy controller can be managed remotely during trial in actual environments. Experimental results showed that the learned fuzzy expert controller controls the self-driving car during the path tracking and precisely performs the execution of different maneuvers.

Planning of the Coordination of Multiple Quadrotors Applied to the Transport of Materials
Walber Lima Pinto, Junior, Luiz E. Santos Araújo, Filho and Cairo L. Nascimento, Jr. (Instituto Tecnológico de Aeronáutica, Brazil); Sergio Ronaldo Barros dos Santos (Federal University of Sao Paulo, Brazil); Wagner Cunha (Instituto Tecnologico de Aeronautica, Brazil)

The problem of resource allocation is still a large study area, where different techniques are applied to find an optimal or sub-optimal solution to the problem. This work presents a solution to this problem that uses a Reinforcement Learning technique called Learning Automata, in conjunction with the A* heuristic search algorithm, to allocate material transport tasks to multiple agents and calculate routes to perform these tasks. The vehicles used as agents are small quadrotors.

The A* algorithm was applied to generate optimal local routes for each carrier and occasionally resolve conflicts between them. Diagonal distance heuristics were used and a small modification was made to the algorithm that avoids convergence to a non-optimal route. A Pure Pursuit path tracking algorithm was used to give velocity commands to the agents in order to follow the path reference given by the A* algorithm.

The various analyzed cases of the learning algorithm and a scalability test showed that the proposed solution is capable of finding sub-optimal solutions in a reasonable time for small and medium scale problems, showing that the route plan learned can solve the proposed tasks. The solutions were applied in the Gazebo simulation environment where the communication with the learning algorithm on MATLAB has been done via ROS.

Extending ISO26262 to an Operationally Complex System
Jennifer Dawson and Divya Garikapati (Toyota Research Institute, USA)

ISO 26262 is a tailored functional safety specification for electrical and electronic systems in passenger vehicles. Typical passenger vehicles have one controlling agent (the driver) and typically utilize simple fail-safe behaviors to notify the driver of significant system faults, such as activating a warning light. Developing advanced safety systems, with the ultimate goal of achieving Level 5 autonomy, has created a need to develop operationally complex passenger vehicles to test self-driving technology. One example of such a system is a Dual-Cockpit vehicle that has been specifically designed to enable human factors research for TRI's Guardian system. Toyota Guardian anticipates or identifies a pending incident and seamlessly intervenes to assist the human driver to form a mobility teammate.

This paper presents a methodology to leverage ISO 26262 methodologies, which are well-established in the automotive industry, to be able to handle significant operational complexity. The methodology develops a Concept of Operations (ConOps) defining operational modes. Vehicle-level behaviors are then defined to achieve a safe state across all operational modes defined in the ConOps. The safe state behaviors are integrated into ISO 26262 work products such as the HazOp, HARA, and Functional Safety Concept, including Functional Safety Requirements. This generalized methodology: 1. facilitates systematic analysis of control authority arbitrations between multiple independent controlling agents, 2. helps ensure sufficient system redundancy across all operational modes, and 3. develops appropriate responses to bring the vehicle to a safe state in each operational mode. The methodology can be adapted to other complex systems with ease.

Keywords- Autonomous systems, automotive systems, complex systems, ConOps, dual-cockpit, functional safety, HazOp, HARA, human factors research, ISO 26262, systems engineering, systems engineering methodologies, system verification.

Cloud Computing

A Failure Prediction Model for Large Scale Cloud Applications using Deep Learning
Mohammad Jassas (University of Ontario Institute of Technology, Canada); Qusay Mahmoud (Ontario Tech University, Canada)

Many cloud service providers face significant challenges in preventing hardware and software failure from occur-ring. Due to the large scale and heterogeneous nature of cloud computing, cloud services continue to experience failures in their components. A significant proportion of previous studies have focused on the characterization of failed jobs and understanding their behavior, while a few studies have focused on failure prediction, with a focus on increasing the accuracy of failure prediction models. This paper presents the development and implementation of a failure prediction model using a deep learning approach. The proposed model can identify and detect failed tasks early on before they occur. The key feature of the failure prediction model is to improve the performance of cloud applications by reducing the number of failed jobs. In order to investigate the behavior of failure and apply the prediction of failure to the large-scale environment, we used three different traces, namely Google Cluster Trace, Mustang and Trinity. Moreover, we have evaluated the proposed model performance using different evaluation metrics to ensure that the proposed model provides the highest accuracy of predicted values. The proposed model is designed and implemented to achieve high accuracy for failure prediction, regardless of whether the model uses a large or small trace size. The evaluation results show that our proposed model achieved a high precision, recall and f1 score.

Performance Evaluation of Distributed Systems in Multiple Clouds using Docker Swarm
Nitin Naik (Aston University, United Kingdom (Great Britain))

A distributed system is a collection of interconnected independent systems that enables systems to coordinate their activities and share their resources for acting as one large virtual system [1]. The design of distributed systems poses many challenges such as successful handling of failure of machines, disks, networks, and software [2]. The design of distributed systems in multiple clouds have been gaining popularity due to various benefits of the multi- cloud infrastructure such as minimizing vendor lock-in, data loss and downtime [3]. Nonetheless, multi-cloud infrastructure also poses several challenges such as compatibility, interoperability, complex provisioning and configuration due to the variation in technologies and services of each cloud provider [2], [4]. Consequently, it is a tedious task to design distributed systems in multiple clouds. Virtualization is regarded as the base technology of the cloud and therefore, most cloud-based distributed systems are based on it [5]. Nevertheless, virtual machines demand substantial resources and cause several issues across multiple clouds such as provisioning, configuration management, load balancing and migration [5], [6]. These issues make it unprepossessing for various types of systems and adversely affect its performance efficiency [6]. Docker Swarm is a container-based clustering tool that supports the design of distributed systems in multiple clouds [3]. It has also incorporated several inbuilt attributes of the distributed system to increase the performance efficiency of these systems [5]. Nonetheless, Docker Swarm is still in the early stage of development with the little establishment in the production environment and its ecosystem is not fully grown. Therefore, it is crucial to examine its distributed features and the performance efficiency against virtualization and other container-based distributed systems.

Therefore, this paper will present the simulated development of a distributed system in multiple clouds using Docker Swarm and evaluates its performance efficiency against virtualization and other container-based distributed systems. The paper will demonstrate the experimental evaluation of several attributes of the distributed system such as high availability, scalability, load balancing and maintainability. The paper will present:

1. Background information of Containerisation, Docker Container and Docker Swarm.
2. Architectural design of the proposed multi-cloud distributed system.
3. Simulation of the proposed distributed system on five different clouds: Amazon Web Services (AWS) EC2 cloud, Azure cloud, Google Compute Engine (GCE) cloud, Digital Ocean cloud and IBM Softlayer cloud.
4. Experimental evaluation of high availability of clusters.
5. Experimental evaluation of automatic scalability, load balancing and maintainability of services.
6. Experimental evaluation of resource and energy efficiency.
7. Experimental evaluation of orchestration of large clusters in multiple clouds.
8. Experimental evaluation scalability of large clusters.
9. Trade-offs of the proposed Docker Swarm-based distributed system.

System execution path profiling using hardware performance counters
Francis Giraldeau (Polytechnique Montreal, Canada); Naser Ezzati-Jivan (Brock University, Canada); Michel R. Dagenais (Ecole Polytechnique de Montreal, Canada)

The task critical execution path, obtained from a kernel trace, reports the time spent waiting for each task involved in a heterogeneous and distributed application. However, additional profiling is needed to understand and identify the problematic code associated with long-lasting path edges. Hardware counter sampling provides insight on software performance at the microarchitecture level, for instance extracting the call stack every 100K execution cycles to understand where the execution time is spent. Similarly, extracting the call stack at the end of a long waiting system call is often useful. This technique is readily available for either statically or JIT compiled code. However, interpreted code is indirectly executed on the processor and the link between the statements and the executed assembly is missing. We propose an architecture to efficiently record call stacks along the execution path, including interpreted programs, in a low intrusive way that maintains the abstraction boundary between the kernel, the interpreter, and the user code. The method consists in sending a signal from within the performance counter interrupt handler. The user-space code receiving the signal can inspect and record the state of the program. We implemented a profiler for the CPython interpreter using this technique. We studied the benefit, the accuracy, and the cost of the proposed technique compared to an all-kernel monitoring solution.

Complex Systems

Optimization of Deep Reinforcement Learning with Hybrid Multi-Task Learning
Nelson Varghese and Qusay Mahmoud (Ontario Tech University, Canada)

Driven by the recent technological advancements within the field of artificial intelligence (AI), deep learning (DL) has been emerged as a promising representation learning technique across all of the machine learning classes, especially within the reinforcement learning (RL) arena. This new direction has given rise to the evolution of a new technological domain named deep reinforcement learning (DRL) that combines the high representational learning capabilities of deep learning with existing reinforcement learning methods. Undoubtedly, the inception of deep reinforcement learning has played a vital role in optimizing the performance of reinforcement learning-based intelligent agents with many model-free based approaches. Optimization of the performance achieved with this methodology was majorly limited to systems with reinforcement learning algorithms focused on learning a single task. Simultaneously, the aforementioned approach was found to be quite data inefficient, particularly when reinforcement learning agents needed to interact with more complex and rich data environments. This is primarily due to the limited applicability of deep reinforcement learning algorithms to many scenarios across the related tasks from the same distribution. One of the possible approaches to mitigate this issue is by adopting the method of multi-task learning. Objective of this research paper is to present a parallel multi-task learning (PMTL) approach for the optimization of deep reinforcement learning agents operating within two different by semantically similar environments with related tasks. The proposed framework will be built with multiple individual actor-critic models functioning within each environment and transferring the knowledge among themselves through a global network to optimize the performance.

Real-Time Edge Processing Detection of Malicious Attacks Using Machine Learning and Processor Core Events
Rob Oshana (Southern Methodist University & NXP, USA)

A method for the detection of malicious events such as the SPECTRE exploit is proposed and evaluated using machine learning and processor core events. In this work, we use machine learning to implement a system based on hardware event counters to detect malicious exploits such as SPECTRE running in a process on a Linux based system. Our approach is designed to use existing on-chip hardware to detect a SPECTRE-based exploitation in real time. Prototype architectures in both x86 and ARM-based SoC's representing an embedded system with a corresponding real-time Edge-based classifier is designed and implemented to validate the approach. This exploit detection architecture uses software agents and requires no additional hardware. In particular, a software agent periodically accesses the event counter register file during runtime. At each observation time, a feature vector is formulated consisting of a particular subset of event counter data. The event counter data used in the detection technique includes cache and branch prediction counts. Various different machine learning classifiers are implemented with a goal of predicting either the presence of the malicious exploit or something other than the malicious exploit. Thus, the classifier outputs binary states of "malicious exploit present" versus "normal operation." Many classifiers resulted in true positive rates in excess of 98% with corresponding false positive rates less than 1%. In many cases, a 0% false positive rate is achieved. These predictive approaches are compared for training complexity and performance.

Infusion Complexity: Understanding the Need to Measure Infusion Success of Advanced Technologies into Complex Systems
Cinda Chullen (Stevens Institute of Technology & NASA, USA); Roshanak Rose Nilchiani (Stevens Institute of Technology, USA)

Once a technology is deemed ready to infuse into a legacy or parent system, the infusion process becomes fussy and it becomes difficult to measure the success of that infusion. This paper concentrates on that infusion and introduces the concept of "infusion complexity." The complexity at the interface of infusion of a new technology into a legacy system can contribute to the success and smooth transition into an integrated system, or in contrast, can create unforeseen emergent behavior and challenges in the infusion problem. Therefore, gaining deep knowledge and assessing the complexity of the infusion is critical and can shed light on the success or lack thereof the infusion of the two complex systems. With minimal literature existing in this area, a deeper dive into technology infusion into complex systems is needed. A literature survey was performed and sets the landscape for what has currently been accomplished in terms of technology readiness and assessment, integration and system readiness, technology infusion in complex systems, engineering change, and associated research. Overall, the paper communicates the need to understand and measure the success of infusing a new or advanced technology into a complex system through the necessity for a measure of infusion complexity.

Time Optimal Concurrent Data collection Trees for IoT Applications
Arvind Kumar (Indian Institute of Information Technology Guwahati & Jaypee University of Information Technology, India); Rakesh Matam (Indian Institute of Information Technology Guwahati, India); Mithun Mukherjee (Guangdong University of Petrochemical Technology, China)

An Internet of things (IoT) application is typically comprised of a set of smart devices that generate and exchange vast amounts of data. Multiple applications can cooperate and share the same device infrastructure to meet their respective sensing needs. Also, multiple subscribers to the same data benefit from such a shared network set-up. The data generated by these devices is analyzed to increase productivity. Also, it is also used to improve the safety and security. A typical IoT network consists of a few hundreds of interconnected devices, and multiple application processes depend on the data generated by these devices. To prevent over provisioning, these applications cooperate and share the same device infrastructure to meet their respective sensing needs. This, however, presents the challenge of concurrent data collection. In concurrent data collection processes, multiple parallel data streams can be used to collect data efficiently at numerous base stations. Existing designs of concurrent data collection trees introduce many new challenges for IoT applications. One such challenge is the delay optimization of the concurrent data collection processes. In this paper, a time-optimal concurrent data collection trees is proposed. Through simulations, we show that the data collection is faster using the proposed structure in comparison to the existing design.

An Initial Set of Heuristics for Handling Organizational Complexity
Dean Beale and Theo Tryfonas (University of Bristol, United Kingdom (Great Britain))

The inability to handle rising complexity effectively is often the cause of project, organizational, enterprise, and even societal collapse. A tractable set of heuristics for handling complexity that can mitigate this risk is consequently highly sought. However, conventional experience-based approaches for identifying complexity handling advice tend to lead to informed but complicated constructs that may be considered over-prescriptive and burdensome for handling complex problems, especially when the need for this support is acute. Further the cacophony of advice, with their tailored lexicons, can cause organizational confusion. This paper explores the development of a simple set of heuristics using an inductive approach that seeks to reduce the decision space and add insight without being overly prescriptive or complicated. An initial set of Heuristics are developed using first-principles. These are then tested and proven by comparison with the dominant discourse in a literature search, to assess if they are simplifying and contributing to established practice, and assessed in a survey to determine if they are useful compared to other similar sets. It is concluded that the proposed set are more useful than similar sets, and that the simplified set of seven heuristics should be developed further to complement other approaches that aim to inform decision-makers in projects, organizations, and society as they seek to handle complexity effectively.

K-Shell Decomposition of AS Level Multigraphs
Abdullah Yasin Nur (University of New Orleans, USA)

The Internet is one of the immense human-engineered systems and understanding of the topology can be helpful for network engineers and researchers. Categorization of Autonomous Systems (ASes) plays an essential role in understanding the structure and evolution of the Internet. However, the traditional categorization exhibits variation in different studies, contains ambiguity, involves subjectiveness, and sometimes does not match the reality. A better approach to classify ASes is defining the AS level topology maps as graphs and taking advantage of the graph properties through k-shell decomposition. However, the proposed solutions neither capture the parallel connections nor incorporate the varying business relations among the ASes. Abstracting ASes without any internal structure is an oversimplification since the ASes in the Internet span over various geographic regions and often cover the same regions in part or whole. In this work, we introduce k-shell decomposition on AS level multigraphs and comparison with AS level graphs. The decomposition is based on pruning the graphs according to the nodes' connectivity pattern to generate a layered structure of the Internet. In our experiments, we analyze the structure of the shells and the connectivity structure of the Internet. Additionally, we compare top-20 ASes to understand the central core of the Internet. Our comparative results help us to understand the structure of the Internet better.

Cyber Security

Trusted Inter-Process Communication Using Hardware Enclaves
Newton Carlos Will (Federal University of Technology - Parana, Brazil); Tiago Heinrich and Amanda Viescinski (UFPR, Brazil); Carlos A Maziero (Federal University of Parana State - UFPR, Brazil)

Inter-Process Communication (IPC) enables applications to share information in a local or distributed environment, allowing them to communicate with each other in a coordinated manner. In modern systems this mechanism is extremely important, as even local applications can run parallel tasks in multiple processes in the machine, needing to exchange information to coordinate their execution, and optimizing the exchange of data in a more efficient way. The security in IPC relies on the integrity and confidentiality of the messages exchanged in such an environment, as messages exchanged between different processes can be targeted by attacks that seek to obtain sensitive data or to manipulate the application behavior. A Trusted Execution Environment (TEE) can be used to enable an isolated execution of the IPC mechanism to mitigate such attacks. In this paper we propose the adoption of the Intel Software Guard Extensions (SGX) architecture to provide data confidentiality and integrity in message exchange between processes, by using hardware instructions and primitives to encrypt and authenticate the messages. Our approach highlights a threat model and compares the solution proposed with two other scenarios, showing a feasible solution for security and an approach that can be applied to standard IPC mechanisms with small processing overhead.

SocialSDN: Design and Implementation of a Secure Internet Protocol Tunnel Between Social Connections
Michael Lescisin and Qusay Mahmoud (Ontario Tech University, Canada)

End-to-end encrypted (E2EE) network services can be classified into 1) network services that provide native end-to-end encryption and 2) non-encrypted services transported through secure tunnels. While the first solution of native E2EE applications lacks generality and standardization, the second option of secure tunnels shows itself to be a promising solution, yet the current state-of-the-art still possesses several drawbacks. Primarily, the current state-of-the-art for establishing a secure tunnel for arbitrary IP traffic between two or more users requires significant technical expertise. Secondly, due to side-channel effects, the current state-of-the-art for cryptographically protected network tunnels may leak sensitive information through traffic pattern analysis. Lastly, the current state-of-the-art for this type of networking lacks elegance and convenience and therefore users often settle for less secure non-E2EE services. In this paper, we present SocialSDN which utilizes concepts from social networking and software-defined networking to build a tool which addresses many of the issues holding back mass adoption of E2EE network services.

The main research contribution of this paper is the design of a tool for establishing peer-to-peer connections for sharing networked applications, along with the open-source release of its implementation. As secondary research contributions, we provide a review of the state-of-the-art in encrypted network tunnel solutions, in addition to a demonstration of a side-channel information leak that results with the use of variable bit-rate codecs in VoIP applications.

Evaluating the Use of Technology Readiness Levels (TRLs) for Cybersecurity Systems
Jeremy Straub (North Dakota State University, USA)

Technology readiness levels (TRLs) were developed by the National Aeronautics and Space Administration (NASA) to classify technologies' readiness for mission use. A TRL classification allows mission developers to rapidly determine what level of risk they would be undertaking by selecting a particular technology. The TRL also suggests how much technology investment may be required to bring a technology to a point where it can be used in a given mission. TRLs can also be used by mission managers, mission portfolio managers and other decision makers to understand the likelihood of mission failure across multiple missions and to understand missions' technology risk posture. However, despite its criticality across numerous areas and the considerable risk that it presents, no similar readiness system is available for cybersecurity. In fact, based on the current NASA classification definitions, a system could have a high TRL level while having significant security issues.

While the TRL system was pioneered by NASA; however, other agencies, including the United States departments of Homeland Security, Defense and Energy have also developed related systems. This paper proposes the use of a cybersecurity capability readiness level system to assess and characterize the readiness status of cybersecurity systems for use. It discusses the existing readiness level systems as well as the Cybersecurity Maturity Model, comparing and contrasting them. A new system, based on the TRL system, which can be used across multiple agencies' readiness systems, is proposed and its levels are defined and discussed.

Offensive Cyber Security Trainer for Platform Management Systems
Jonathan Timmins (Royal Military College of Canada & Computer Security Lab, Canada); Scott Knight (RMC, Canada); Brian Lachine (Royal Military College of Canada, Canada)

To protect its platforms against cyber attacks, the Royal Canadian Navy (RCN) must train specialists in platform cyber security. These specialists will need to understand the offensive capabilities of their adversaries in order to defend these platforms and to develop more secure systems. As a result, these specialists will require an environment which can facilitate training in offensive cyber security techniques. Currently, no cyber security trainer exists for the RCN's Platform Management Systems (PMS), nor does one exist for any of the RCN's other platform systems. The aim of this research is to develop a PMS environment based on effective training techniques and capable of training RCN personnel in offensive cyber techniques. Effective training techniques in this context will reflect best practices from pedagogical literature. The training environment in this case is an offensive cyber security trainer which facilitates the training of personnel to execute cyber kill chains mapped from real attacker tactics, techniques, and procedures. Training cyber defenders to perform these kill chains will provide them with a greater understanding of how attacks can be executed against RCN platform systems. This in turn will enable the RCN to better defend against such kill chains. In order to accomplish this aim, an offensive cyber security trainer for a PMS is developed which utilizes a combination of simulation, emulation, and virtualization to provide an effective level of control and flexibility while also maintaining a high level of realism. This training also specifically leverages a Capture the Flag (CTF) framework to enhance personnel engagement within the environment. The functionality of this trainer is demonstrated by its ability to facilitate the training program and the execution of multiple kill chains against the PMS. The effectiveness of the trainer is validated on its application of current research methodology in effective gamified training environment design.

Network Traffic Flow Based Machine Learning Technique for IoT Device Identification
Imtiaz Ullah and Qusay Mahmoud (Ontario Tech University, Canada)

Security and privacy issues are being raised as smart home systems are integrated into our households. New security issues have emerged with several new vendors that develop the Internet of Things (IoT) products. New methods of network assessment are needed to evaluate the type of network-connected IoT devices. IoT device recognition would provide a comprehensive structure for the development of stable IoT networks. This paper chooses a machine learning technique to classify IoT devices linked to the network by analyzing network flows sent and received. To produce network traffic data, we developed a dataset adapted from the IoT23 dataset to experimental a smart home network. We have created a model to identify the type of IoT device based on network traffic analysis. We evaluate our proposed model via full features dataset, reduces features dataset, and flow-based features dataset. This paper focuses on using flow-based features to identify an IoT device. Methods and techniques for flow-based identification just examine packet headers to identify the network traffic. Our proposed model obtains 100% accuracy, precision, recall, and F score via full features dataset, reduces features dataset, and flow-based features dataset. Through evaluations using our produced dataset, we demonstrate that the proposed model can accurately classify IoT devices.

Systematic Mapping on Prevention of DDoS Attacks on Software Defined Networks
Alfredo Menezes Vieira (Federal University of Sergipe, Brazil); Rubens S. Matos, Jr. (Federal Institute of Education, Science, and Technology of Sergipe, Brazil); Admilson de Ribamar Lima Ribeiro (Federal University of Sergipe, Brazil)

Cyber attacks are a major concern for network administrators as the occurrences of such events are continuously increasing on the Internet. Software-defined networks (SDN) enable many management applications, but they may also become targets for attackers. Due to the separation of the data plane and the control plane, the controller appears as a new element in SDN networks, allowing centralized control of the network, becoming a strategic target in carrying out an attack. According to reports generated by security labs, the frequency of the distributed denial of service (DDoS) attacks has seen an increase in recent years, characterizing a major threat to the SDN. However, few research papers address the prevention of DDoS attacks on SDN networks. Therefore, this work presents a Systematic Mapping of Literature, aiming at identifying, classifying, and thus disseminating current research studies that propose techniques and methods for preventing DDoS attacks in SDN networks. When answering the research questions it was identified, the vulnerability of SDN networks with possible DDoS attacks to the SDN controller. It was also possible to identify the absence of work that works in the first phase of the attack, in which the attackers try to deceive the user and perform the infection of the host.

Anomaly Detection Technique for Intrusion Detection in SDN Environment using Continuous Data Stream Machine Learning Algorithms

Admilson de Ribamar Lima Ribeiro (Federal University of Sergipe, Brazil); Reneilson Santos (Universidade Federal de Sergipe, Brazil); Anderson Nascimento (University of Washington Tacoma, USA)

Software Defined Networks (SDN) present some security weakness due to the separation between control and data planes. Thus, several operational security mechanisms have been developed to mitigate malicious activity in SDN. However, most of those mechanisms require a signature basis and present the inability to predict new malicious activity. Other anomaly based mechanisms are inefficient due to the possibility of an attacker to simulate legitimate traffic, which causes many false alarms. Thus, in this paper, we present an anomaly based technique that makes use of machine learning algorithms over continuous data stream for intrusion detection in a SDN environment. Our approach is to overcome the main challenges that happen when developing an anomaly based system using machine learning techniques. For characterising the anomalies, we analysed two types of internal DDoS attacks that can occur in a SDN environment. We have analysed a type of DDoS attack classified as infrastructure attack that considers the impact of both bandwidth and resource depletions. This type of attack imposes a high affect to the whole SDN. In fact, there are two types of attacks. The bandwidth depletion attack targets the channel between the switches and the controller through either UDP or HTTP flooding. Another way to exhaust outgoing and ingoing bandwidths is through ICMP flooding. The resource depletion attack attempts to exhaust the flow table of switches through SYN flooding. In the experiments, we show that the technique attains an accuracy of 97.83%, a recall of 99%, a precision of 80% and a FPR of 2.3% for 10% DDoS attacks on the normal traffic. This shows the effectiveness of our technique.

Single Packet AS Traceback against DoS Attacks

Abdullah Yasin Nur (University of New Orleans, USA); Mehmet Engin Tozal (University of Louisiana at Lafayette, USA)

The Internet is every facet of our daily lives and becomes more pervasive every day. It is designed to forward packets with minimal intervention, including malicious packets. This design enables different attack types including Denial of Service (DoS), which is one of the most harmful cyber-attack types in the Internet. In this work, we propose an Autonomous System (AS) traceback packet marking scheme to infer AS level forward paths from attackers towards a victim site. We utilize the Record Route option of the IP protocol to implement our packet marking scheme. Traceback on the AS level has many advantages, including a significant reduction in the number of required packets to construct forward-paths from attackers toward a victim site, reduction in the number of routers that involves in the packet marking process, and lower packet size overhead to routers, comparing to Interface level traceback. Our results show that a victim site can construct the AS level forward path from an attacker site after receiving a single packet. In our marking algorithm, we provide an encoding method to reduce the bandwidth usage. The proposed technique uses 96.91 bits on the average in the Record Route options field, whereas the unencoded version uses 153.96 bits on the average.

A Generic Model for Privacy-Preserving Authentication on Smartphones
Sepehr Keykhaie (Polytechnique Montréal, Canada); Samuel Pierre (Ecole Polytechnique de Montreal, Canada)

With the increasing use of biometrics for user authentication especially on mobile devices, its privacy and resource requirements are becoming big challenges to consider. In this paper, we propose a generic model for privacy-preserving yet accurate authentication on smartphones using the mobile matching on card (MMOC) technique and transfer learning. MMOC technique takes advantage of SIM cards as a secure element (SE) on smartphones to increase the security and privacy of user verification with low performance overhead. In order to improve the performance accuracy of the system, we use transfer learning and fine-tune a network suitable for implementation on off-the-shelf SIM cards available on smartphones. The classification sub-network is migrated to the SIM card for a lightweight and secure user verification. However, the implementation of classification sub-network on constrained resource smart cards with high accuracy and efficiency is a challenging task. We propose log quantization scheme and an on-card optimization architecture to speed-up the forward pass of the sub-network and retain the system's accuracy close to the original model with low memory footprint and real-time verification response. Using a public mobile face dataset, we evaluate our privacy-preserving verification system. Our results show that the proposed system achieves Equal Error Rate (EER) of 0.4%-2% in real-time, with response time of 1.5 seconds.

Secrecy of Multi-Hop DF Communications with a Line-of-Sight Access Link
Xian Liu (University of Arkansas at Little Rock, USA)

Decode-and-forward (DF) is one of the most representative schemes in multi-hop cooperative communication (a.k.a. relaying communication) systems. The secrecy analysis is more involved when there is a line-of-sight link presented. In this situation, the small-scale fading cannot be described by the Rayleigh model anymore. It needs the more complicated Rice model. However, in multi-hop DF communications, the appearance of Rician variables significantly increase the complexity of analysis. Conventional approaches for evaluating performance of MDF systems have been based on simulations.

In this paper, we investigate the secrecy performance of a generic relay cluster that includes a line-of-sight (LOS) link. We derive several benchmark metrics of this system. These metrics are explicitly expressed in the closed-form. The availability of these solutions helps directly gain the deep insights, while reducing the computational load of tedious simulations. The present work extends the existing works where only the Rayleigh fading was considered and/or only the metric bounds were presented. The results obtained in this paper, due to their simple yet closed-form expressions, could be used to describe some higher level attributes such as the Quality-of-Protection (QoP). We note that currently QoP is receiving ever a high attention in systems engineering. The presented methodology can be easily applied to other scenarios.

Combating DDoS Attacks with Fair Rate Throttling
Abdullah Yasin Nur (University of New Orleans, USA)

Distributed Denial of Service (DDoS) attacks are among the most harmful cyberattack types in the Internet. The main goal of a DDoS defense mechanism is to reduce the attack's effect as close as possible to their sources to prevent malicious traffic in the Internet. In this work, we examine the DDoS attacks as a rate management and congestion control problem and propose a collaborative fair rate throttling mechanism to combat DDoS attacks. Additionally, we propose anomaly detection mechanisms to detect attacks at the victim site, early attack detection mechanisms by intermediate ASes, and feedback mechanisms between ASes to achieve distributed defense against DDoS attacks. To reduce additional vulnerabilities for the feedback mechanism, we use a secure, private, and authenticated communication channel between AS monitors to control the process. Our mathematical model presents proactive resource management, where the victim site sends rate adjustment requests to upstream routers. We conducted several experiments using a real-world dataset to demonstrate the efficiency of our approach under DDoS attacks. Our results show that the proposed method can significantly reduce the impact of DDoS attacks with minimal overhead to routers. Moreover, the proposed anomaly detection techniques can help ASes to detect possible attacks and early attack detection by intermediate ASes.

Impact Evaluation of DDoS Attacks Using IoT Devices
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Distributed Denial-of-Service (DDoS) attacks can occur anytime, everywhere, and most normally occur with little or no warning. Most small and medium businesses (SMBs) usually are not prepared to deal with this type of attack. The companies must have at least a bandwidth higher than the attack, an infrastructure with redundant components, regular backups, and firewalls capable of monitoring the threats. Otherwise, the services provided by the companies' support can be interrupted, increasing the chances of financial losses. Hierarchical modeling approaches are often used to evaluate the availability of such systems. It can represent different failures and repair events in distinct parts of the system. In this way, this paper proposes hierarchical models that describe the behavior of major IT systems and IoT device components and assess the DDoS effects on system availability. Therefore, we evaluate the impact of the DDoS attacks on computing systems using IoT devices in attack amplification. We assessed equations that estimate the attack feasibility, pain factor, attack propensity, attacker benefits, and technical ability. They enable a direct analytical solution for large systems. The attack tree indices show the impact of simultaneous attacks on a computer system and the several threats that will maximize the system downtime. The attack tree investigation results allow for planning and improving the system's availability, maintainability, and reliability.

Decision-Making for Complex Systems

A proposal for success criteria and categorization system to a technology introduction program for Oil and Gas innovation projects
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The dynamics of innovation in Complex products and systems (CoPS) is based on projects and differs from the mass production industries. Many of the investments related to CoPS require the development of cutting-edge technologies and their integration into large and complex systems, requiring appropriate methodologies for risk assessment and management in these investments. Projects are not only part of the operational side but are critical to business innovation, capacity development, and corporate strategy. Determining adequate success criteria and establishing a project categorization system are critical for assessing innovation projects.

This article initially shows the proposal and evaluation of the success criteria model for Oil and Gas projects. From this evaluation, a program was proposed to introduce technologies in systems, aiming at evolving systems and their convergence with the corporate strategy. A categorization system was then proposed to assess innovation projects in this program, based on the diamond approach, and it was applied to case studies. The evaluation showed positive results and provided insights about the relative importance of success criteria dimensions. This study contributes to the theory with adaptations to the literature models, a program proposal, and empirical data. Organizations dealing with CoPS, especially in the Oil and Gas sectors, may benefit from the models and insights presented here.

Deploying Different Clustering Techniques on a Collaborative based Movie Recommender
Dina Nawara and Rasha Kashef (Ryerson University, Canada)

Recommendation systems are involved in many industries for example (e-health, transportation, ecommerce, and agriculture). Where Recommendation systems aim to benefit both market and user levels. They help consumers make the right decision based on their preferences without being exposed to the data overload. Nowadays, there are wide range of recommenders based on different filtering approaches, such as Collaborative based, Content based , hybrid based, demographic based filtering approaches. In this paper we present a literature for clustering-based recommendation systems. We also experiment and show the results for a collaborative based movie recommender using different clustering techniques such as, K-means, BIRCH (balanced iterative reducing and clustering using hierarchies) and DBSCAN (Density-based spatial clustering of applications with noise). We intended to choose different clustering approaches such as, the partitional, hierarchical and density based clustering approaches. We incorporated Item-based Collaborative filtering, then applied multiple clustering techniques on the dataset based on the users' ratings. We checked the performance of the algorithms using accuracy measures like MAE (Mean Absolute Error), RMSE (Root mean square error), and also calculated the computed time. These measures were calculated for each clustering technique for analysis and comparison purposes.

Keywords- Recommendation Systems, Collaborative filtering, Clustering, K-means, DBSCAN, BIRCH, Accuracy

Using AHP to Choose Optimal Nuclear Power Plant Design
Lauren Kiser and Luis Daniel Otero (Florida Institute of Technology, USA)

Emerging technologies in nuclear power plant (NPP) design offer decision makers the chance to explore innovative options in the nuclear power industry. Because there are more options available when it comes to NPP design selection than in past decades, having a tool to compare NPP parameters to decision maker priorities could prove useful in business strategy. The operational and safety features of Small Modular Reactors and Molten Salt Reactors address decision criteria differently than the common and traditional Light Water Reactors (LWR). This paper uses the Analytic Hierarchy Process (AHP) to explore and compare the financial, operational, and risk attributes of three nuclear power plant designs and presents a decision-making tool for choosing the optimal design. A pairwise comparison of defined criteria to establish priorities and criteria weights was based on a literature review effort and domain experience with the goals of reducing cost, optimizing plant characteristics, and minimizing risk. Results from the AHP model show the LWR design as optimal. LWRs are the most common type of NPP in operation and expected to have the most favorable public opinion, proven safety features, and lowest licensing costs. Overall, the AHP model presented in this paper reflects some challenges that the emerging NPP designs and technologies must overcome before fully breaking into the mainstream nuclear power industry.

Efficient Traffic Classification Using Hybrid Deep Learning
Farnaz Sarhangian, Rasha Kashef and Muhammad Jaseemuddin (Ryerson University, Canada)

Network traffic classification plays a significant role in network management and administration functions such as QoS, security, and billing. Those functions need a timely and accurate detection of specific traffics. Current network traffic classification methods offer supervised and unsupervised learning capabilities to predict or classify network traffic. Classical machine learning classifiers that use a single classification model suffer from low prediction and classification accuracy, especially for high dimensional datasets with a high level of sparsity. These challenges in individual-based learning models have created a need for hybrid learning. Recently, hybrid-deep learning has shown a significant rule in traffic forecasting and classification due to its efficiency. However, a tradeoff between the aggregate models and the classification accuracy presents a significant challenge in network traffic classification problems. In this paper, we have proposed two hybrid models that combine the Convolutional Neural Network (CNN) along with the Recurrent Neural Network (RNN) models, including the Long Short-Term Memory (LSTM) and Gated recurrent unit (GRU), to improve traffic classification accuracy. The performance of proposed models has been compared to that of various individual-based models using real network traffic traces. Our test results show that the hybrid models have achieved a significant improvement in accuracy and F-score values.

Testing the application of support vector machine (SVM) to technical trading rules
André Fonseca and Michel Leles (Universidade Federal de São João Del-Rei, Brazil); Mariana Moreira (Universidade Federal de São João Del Rei, Brazil); Adriano Vale-Cardoso and Marcos Vinícius Pereira (Universidade Federal de São João Del-Rei, Brazil); Elton Sbruzzi and Cairo L. Nascimento, Jr. (Instituto Tecnológico de Aeronáutica, Brazil)

The movement of the stock market is the result of numerous factors that are often difficult to detect and even more to model. In most cases, the resources spent trying to predict the future value of an asset may not be advantageous. Observing market trends and using the information available to build a trading strategy can be promising. With the idea of building a model that can improve results of investments in a certain asset, it is proposed in this work the use of the concept of support vector machine - SVM - to analyze price movements in the time series of shares of Brazilian companies traded and listed on the Brazilian and American stock exchange B3 and Nasdaq, respectively, using computational tools of machine learning, signaling trading options. Different technical indicators have been used as inputs to the model, and help to make a decision of buying or selling a particular asset based on these market data. The results obtained from the model are compared using several metrics in order to compare its performance against known financial strategies found in literature. It will be seen how effective this model can be in order to enable its use in real operations.

Incorporating Behavior in Attribute Based Access Control Model Using Machine Learning
Majid Afshar (Memorial University, Canada); Saeed Samet (University of Windsor, Canada); Hamid Usefi (Memorial University, Canada)

Preventing unauthorized and illegitimate access to sensitive resources is the primary duty of access control models. However, the malicious activities by authorized users cause significant damages to their underlying systems. In many cases, existing access control models are incomplete in their ability to detect insider abuse, and rather than detecting and preventing insider attack, it seems to still operate by forensic analysis after an attack. Attribute-Based Access Control is a new access control model that can be used instead of other traditional types of access control models, and makes decisions according to the access requests by utilizing users' as well as resources' attributes. However, it still endures a quandary of how to permit the real eligible users to access the resources while blocking abnormal access by authorized users of a system.

In this paper, an Attribute/Behavior-Based Access Control is proposed by understanding and deriving users' behaviors from log files. Not only our model uses the user/resource attributes, but it also utilizes their behaviors to detect the abnormal users even with valid attributes. This model principally uses the behaviors of a given user to grant or deny access requests. The concept of a user's behavior will be introduced, and we present a feature construction method to model users' access behaviors. As the proof of concept, machine learning algorithms are trained and tested using a database from UCI Machine Learning Repository. Experimental results illustrate that our model is efficient, accurate, and promising in detecting authorized users with abnormal behaviors.

Enhancing The Performance of Traffic Classification Methods Using Efficient Feature Selection Models

Farzana Alam, Rasha Kashef and Muhammad Jaseemuddin (Ryerson University, Canada)

In the era of secure communication and the constantly changing pattern of internet applications, traditional packet classification methods fail to achieve the accuracy needed for diverse network management functions. Recently Machine Learning (ML) techniques have been used to design viable packet classification solutions. However, due to the complexity and dynamic feature of internet traffic, efficient packet classification is still challenging for various machine learning algorithms. In this paper, we propose the adoption of feature selection methods through dimensionality reduction to enhance the classifiers' performance. We evaluated the performance of four well-known classifiers, including K-nearest neighbour (KNN), Support Vector Machines (SVM), Decision Trees (DT), and Logistic Regression (LR) with and without feature selection. We used two feature selection methods, including principal component analysis and Autoencoder. Experimental analysis is performed on real traffic datasets with binary and multi-class categories. We assessed each classifier's performance using precision, recall, f-score, accuracy, and ROC. Experimental results show that the Precision, Recall, and F-score for the Multi-class problem are improved by 4.7 %, 6%, and 9%, respectively, after adopting either PCA or Autoencoder methods. The classification accuracy is also improved by up to 13%. We can also conclude that Autoencoder performed better for the KNN and LR, while PCA achieved comparable results for both the SVM and DT classifiers.

Defense Systems

System Design of the Rifleman of the Future
Vikram Mittal, Samuel Herbert, Gene Lesinski and James Enos (United States Military Academy, USA)

The rifleman will play a crucial role in future conflicts, so it is imperative that the Army outfits them with the right equipment. However, there is a tendency to provide them with every new technology as it becomes available. This results in a situation where the rifleman is overloaded with technology, only some of which is relevant to the mission. This effect can be resolved by treating the rifleman as a system, comprised of a soldier that is integrated with equipment, focused on performing a mission. This study uses model-based systems engineering to design the rifleman of the future, looking out to 2050. This analysis initially develops a functional model of the current rifleman, identifying the functions and subfunctions that they perform. They must be able to shoot, move, communicate, survive, and sustain. These functions are then allocated against the current equipment set including rifles, body-armor, and radios. The functional model is then updated to reflect the future mission set of the rifleman. The updated functional model is aligned against the current equipment set to identify gaps and needs. New technologies are then allocated against these gaps and needs. The goal of this analysis is to divest from science fiction and focus on what the future rifleman will need to win on the battlefield.

Method for Self-Healing Course of Action Revision (SCOAR)
Paul C. Hershey (Raytheon, Inc., USA)

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. The problem addresses a key aspect of this problem, that of providing an autonomous method for generating and revising a mission plan, sometimes referred to as a Course of Action (COA), during mission execution, especially when an unexpected change of events occurs (e.g., change in the Rules of Engagement). This process is called the Method for Self-Healing Course of Action (COA) Revision (SCOAR).

A key contribution of SCOAR is that of revising a COA without having to generate the COA from scratch. For example, asset positions, maintenance, and tasking are all actively monitored. If the primary asset suffered attrition or was unable to complete its goals during an executing mission, the next best asset would automatically try to take on its role. If no assets are available, the invention will then try to get to the same end state by swapping out the COA activity being performed for an activity in a different COA.

Previous approaches require that the COA generation process restart from COA planning through analysis and feasibility and eventually re-generation from the start of the mission. To repeat this entire process takes time, so much so that it may preclude the new COA from being implemented for the mission at hand. To fully address this problem, an autonomous method is required encompasses COA revision without having to complete the entire COA generation process from COA planning, to COA analysis, to COA generation. This new revision process must also account for additional mission functions such as feasibility analysis and readiness assessment that together provide the mission operator guidance on how to execute an end-to-end mission.

The SCOAR method was implemented with a prototype that generated Probability of Success with Confidence interval results for three alternative COAs

The structure of this paper is organized as follows: Section II discusses related works, and Section III introduces the SCOAR approach, including its architecture and design. Section IV describes the first realization of the SCOAR prototype system and presents preliminary results from that realization. Section V includes conclusions and suggestions for future work.

Energy Management and Sustainability, including Renewable Energy

CO2 Emissions Forecasting in Multi-Source Power Generation Systems Using Dynamic Bayesian Network

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Climate change is one of the significant challenges that the planet is facing nowadays. CO2 emission is the largest contributor, and it is mainly released by human activities. In Europe, the energy sector is responsible for roughly two-thirds of all greenhouse gas (GHG) emissions and the amount of CO2 emitted from electricity production can greatly vary in time as a function of sources used to generate it. An accurate prediction of CO2 emissions not only provides a basis for policymakers, but it can also assist the management of carbon emissions in making efforts towards limiting emissions generation and global warming as a consequence. For such a purpose, researchers have proposed the use of traditional algorithms for forecasting CO2 emissions from the energy sector. However, there still are challenges yet to be overcome as regards forecasting CO2 emissions from the energy sector. Power dispatch problem consists in planning the use of all available sources for minimising the environmental impact while at the same time satisfying the energy demand, stressing the necessity to dealing with this topic in multi-source power generation systems. In this sense, this paper presents the use of discrete Dynamic Bayesian Networks (DBN) to forecast CO2 emissions in a multi-source power generation system. The proposed methodology has been evaluated using the multi-source Germany grid data. The results were benchmarked against Multilayer Perceptron (MLP), K-nearest neighbor algorithm (KNN) and Random Forest (RF), and it was found that DBN achieved a significantly better performance due to reducing average NRMSE by 16.57%, average MAE by 19.88 gCO2eq/kWh and average MedAE by 27.48 gCO2eq/kWh in comparison with the second best method.

Emission Mitigation Dispatch Solved by Deep Learning

Xian Liu (University of Arkansas at Little Rock, USA)

It is imperative to develop effective methods for reducing the gaseous pollutants produced from electric power generation process. In particular, in electricity load dispatch complemented by wind power, it is highly desirable to develop a quick scheme to adjust the real power generated by thermal units. Conventional optimization procedures involve many iterations, thus slow. In this paper, we investigate how to customize the deep learning (DL) methodology to solve such a problem. DL is one of the rapidly developing areas in modern artificial intelligence (AI) studies. Compared with the conventional machine learning (ML) schemes, DL has the advantage to alleviate the computational burden.

In the present work, we focus on a typical issue: the NOx emission, hence emission mitigation dispatch (EMD). A system of 36 generators and 50 wind turbines is chosen as a case study. The DL scheme is implemented with the feed-forward neural network (FNN). All stages of DL, namely training, validation, and testing, are covered in the simulation. It is shown that the training and validation achieved the expected performance criteria. By using the trained FNN, the time of solving EMD is significantly reduced. It is perceived that the DL approach has a good potential for other types of EMD problems.

Dependability and Sustainability Evaluation of Data Center Electrical Architectures
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Faced with the demand to maintain the high availability of data centers (DC), companies are being pressured to seek sustainable alternatives, given that these infrastructures consume a total of 1% of all electricity worldwide. In a time of pandemic (COVID-19), when the digital economy has assumed an even greater share of representativeness, DCs and telecommunications companies need to meet the requisitions of "everything-as-a-service". Linked to this are the large amounts of carbon dioxide (CO2) emitted into the atmosphere due to the production and consumption of energy caused by these infrastructures. Given the above, this paper proposes models of energy flow and reliability block diagrams to quantify the environmental impact from different raw materials used to feed the data center loads and computes sustainability and dependability metrics for the entire DC's power infrastructure. According to the specifications for classifying the tiers, this study's hybrid modeling is performed to represent four different electrical architectures. From the model evaluations, we compare whether the availability achieved corresponds to the minimum availability suggested for each tier and show the emissions of CO2 in the atmosphere for each tier over a year. Besides, we apply a parametric sensitivity analysis technique to identify the most critical components for the modeled systems' availability.

Engineering Systems-of-Systems

A Systems Theoretic Perspective on Systemic Risk in Transfer Learning Systems
Tyler Cody (University of Virginia, USA)

Learning systems are being deployed widely in large scale systems. Both a desire to deploy machine learning and deployment itself has led to the aggregation of data and models into repositories. In an effort to address constraints such as a lack of data, transfer learning is becoming increasingly common in practice. Transfer learning uses knowledge from some source learning systems to help learning in a particular target system. In engineering practice, this has been field by the growth of such repositories. Wide-spread use of transfer learning establishes inter-linkages between otherwise disparate parts of systems. These inter-linkages create systemic risk across a system's learning systems which can spread to the system as a whole. This systemic risk is not only an algorithm design problem, but also a systems engineering problem. We use systems theory to identify catalysts and pre-conditions for systemic failure in transfer learning systems. We discuss catalysts in terms of notions of disruption and non-stationarity. We discuss pre-conditions in terms of notions of concentration, self-sufficiency, and connectivity. Foreknowledge of catalysts can pre-conditions can inform the engineering of both individual learning systems as well as systems of learning systems. In the full paper, we plan to include examples from unmanned aircraft systems to ground the abstract notions discussed herein.

A model-based approach to document a System-of-Systems
Stephan Baumgart (Volvo Autonomous Solutions, Mälardalen University, Sweden)

The technical evolution enables the development and application of autonomous systems in various domains. In the vehicle domain, we can generally distinguish between single system solutions for example autonomous cars and multiple autonomous or semi-autonomous systems integrated into a system-of-systems.

Both systems may contain safety-critical features and a structured analysis of possible hazards is required. We solely focus on how to ensure safety in a system-of-systems in the scope of this work.

The industrial development processes in the earth-moving machinery domain focus on single human-operated systems and lack clear support for autonomous system-of-systems. Various hazard analysis methods are described in literature and used in industry, but there is no clear support for identifying emergent and dysfunctional behavior as observable in a system-of-systems. Generally, every hazard analysis method requires a clear input to ensure that all hazards or critical parts are found or considered.

We utilize a case from the earth-moving machinery domain, where a fleet of autonomous vehicles is utilized for transporting solutions in off-road environments.

In this work, we describe a hierarchical process called SAFESOS, where each step specifies how a system-of-systems is documented to ensure a safety analysis.

We utilize SysML models, but also geographical knowledge for describing a structure and behavior.

This work provides a guideline for practitioners developing a system-of-systems.

Does The Complex SoS Have Negative Emergent Behavior? Looking For Violations Formally
Ramakrishnan Raman (Honeywell Technology Solutions Lab, India); Yogananda Jeppu (Honeywell Technology Solutions, India)

A complex system is characterized by emergence of global properties which are very difficult, if not impossible, to anticipate just from complete knowledge of component behaviors. Emergence, hierarchical organization and numerosity are some of the characteristics of complex systems. Recently, there has been an exponential increase on the adoption of various neural network-based machine learning models to govern the functionality and behavior of systems. With this increasing system complexity, achieving confidence in systems becomes increasingly difficult. Further, ease of interconnectivity among systems is permeating numerous system-of-systems (SoS), wherein multiple independent systems are expected to interact and collaborate to achieve unparalleled levels of functionality. Traditional verification and validation approaches are often inadequate to bring in the nuances of potential emergent behavior in a system-of-system, which may be positive or negative. In this paper, we look for violations formally in the emergent behavior of a complex SoS. The case study pertains to a swarm of autonomous UAVs flying in a formation, and dynamically changing the shape of the formation, to support varying mission scenarios. We use a tool called CBMC which is a bounded model checker that looks at properties in a small defined region and bound and argues on its correctness. The current submission of the paper is the extended abstract version.

Environmental Systems

Modelling of Using Hall Magnetic Sensor for Environmental Monitor of Micrometer-Sized Magnetite Particles

Hua Fan and Huajiang Xie (University of Electronic Science and Technology of China, China)

Hall Magnetic sensors for particles detection have been explored over the past decades. It has been mentioned that the detection has the potential in the applications of biomedicine and environmental monitor. In biomedicine, numerical researches of Hall sensor have been achieved for detecting bio-markers magnetic nanoparticles (MNPs). On the contrary, Hall sensor for environmental monitor is seldom investigated. This paper carries out a pioneering investigation on Hall sensors for air quality detection. A modelling base on finite element method (FEM) software COMSOL is established to quantify the ability of Hall sensors in the measurement of micrometer-sized magnetite particles distributed in the air. Meanwhile, as the development of environmental magnetism in recent years, the modelling has the potential to provide the first prototype of portable sensors for the detection of micro-sized magnetite particles in the air in the future.

Gaming and Entertainment Systems

Automated Extraction and Classification of Slot Machine Requirements from Gaming Regulations
Michael D Prendergast (USA)

Analyzing stakeholder needs and transforming them into requirements is an important early step in the systems engineering lifecycle [1]. In regulated industries, important technical requirements can be found in state and federal laws and regulations. Casino gaming is one such industry. This paper analyzes South Dakota and Nevada slot machine regulations and applies automated natural language processing to extract and analyze technical requirements derived from them. First, the word parts of speech (POS) for the regulations are identified. With these, important adjective and noun keywords and keyword combinations are extracted using the Rapid Automatic Keyword Extraction (RAKE) algorithm [2]. Next, sentences containing requirements are extracted from the gaming laws, many of which lack a "shall" in them. To perform this, a 12-rule pattern matching algorithm that applies phrase substitutions and identifies leader-subordinate paragraph headings is applied to the slot machine gaming rules. This algorithm successfully extracts nearly all of the slot machine technical and operations requirements, though fails to separate compound requirements accounting for approximately 3% of the total. Then, after stemming and stopping the regulations, a Naïve Bayes model for identifying which requirements are functional requirements is constructed from the South Dakota regulations and applied to the Nevada regulations. This model is able to predict the Nevada functional product requirements from amongst the full set of extracted requirements with 87.5% accuracy. Finally, using a modified version of the Dice similarity metric where the word counts are weighted by the term frequency-inverse document frequency (TF-IDF) scores, the South Dakota requirements most similar to each of the Nevada requirements is determined. The paired South Dakota and Nevada requirements are then assessed using systems engineering expertise for equivalency and relatedness. Using the geometric mean of sensitivity and specificity as a scoring metric, the pairing algorithm performance is 96.1% accurate in identifying equivalent requirements between the two sets of regulations, and 82.0% accurate in identifying related requirements.

Medical Systems

Design of a Human Centered Computing (HCC) based Virtual Reality Simulator to train First Responders Involved in the COVID-19 Pandemic
J. Cecil (Oklahoma State University & Cyber Tech LLC, USA); Sam Kauffman (Oklahoma State University, USA)

The COVID-19 pandemic has placed an overwhelming strain on our Nation's ability to treat patients; the number of patients who need to be tested continues to rise. As the first responders continue to tackle the COVID-19 pandemic, it becomes critical to provide proper and efficient training and education to them. In this paper, the design of a VR based simulator to help train first responders in testing and treatment of COVID-19 patients is presented. This paper focuses on exploring the role of Human Centered Computing (HCC) principles in the design and development of such training simulators. HCC factors such as cognitive load has been studied and analyzed during the design process. Participatory design approach has been utilized during the design and development of the VR based simulator to train the first responders. Such a participatory design approach has been useful in providing crucial feedback and suggestions from experts through the design and development process. Furthermore, assessment activities were designed and conducted to assess the impact of such VR based simulators on first responders training. The assessment studies also focused on understanding the role of HCC factors in affecting the users' comprehension and knowledge acquisition is also discussed. The preliminary results from the assessment activities underline the significance of such VR based simulators in the training of first responders.

Identification of Human Centered Design Factors and their impact on Design of Cyber-Human training environments for orthopedic surgery
Avinash Gupta (Oklahoma State University, USA); J. Cecil (Oklahoma State University & Cyber Tech LLC, USA); Miguel Pirela-Cruz (Texas Tech Health Sciences Center, USA)

In this paper, an innovative cyber-human based design approach developed for a VR based orthopedic surgical training simulator is presented. The paper focuses on throwing light on Human Centered Computing (HCC) principles in the design of VR based training environments. HCC principles such as affordance, visual density and cognitive load have been used during the design process. A novel concept of dynamic affordance which is defined as a function of comprehension of the elements of a virtual environment is also discussed in the paper. The orthopedic surgical procedure in focus is the condylar plating surgery which is performed to treat the fractures of femur. Three training environments are also elaborated in the paper which are developed at varying levels of difficulty focusing on various steps of the condylar plating surgery. Challenge scenarios were also developed to assess skills acquisition of the users along with the pre and post-test based knowledge assessments. Furthermore, multiple variants of the environments are designed to assess the impact of HCC factors such as dynamic affordance, visual density and cognitive load on the comprehension, skills acquisition and knowledge acquisition of the users. The results from such assessment activities conducted at two medical hospitals are also presented in this paper.

Systems Design for EEG Signal Classification of Sensorimotor Activity Using Machine Learning
Jacqueline Heaton (Queen's University, Canada); Sidney Givigi (Queen's University & Royal Military College of Canada, Canada)

This paper proposes a systems design for classifying EEG motor movement signals using AI that achieves a high degree of accuracy. EEG motor movement signals are generated by the brain when the subject consciously attempts to move their body. These signals are reflective of the kind of movement they are attempting to achieve, and improving the classification would allow for better assistive devices for the physically disabled. AI classification requires features to be extracted from the raw data. Features can be extracted using different algorithms. The systems design allows the selection of different features. The features used are calculated from the datapoints corresponding to 1 second windows and transformed into the sigma, phi, and omega features. To our knowledge, this is the first time that these features have been used with machine learning techniques. The approach allows the use of different classification models. We test the system with a Support Vector Machine (SVM) and an Artificial Neural Network (ANN), which were both trained on these features, and each window classified independently according to the model. The SVM had an average accuracy of 88%, while the neural network had a higher accuracy of 94%. There was a relatively large amount of variance in the accuracy for different subjects, ranging from 45.9% to 99.6% for the SVM and 24.3% to 99.7% for the ANN. The proof of concept demonstrates that different machine learning algorithms can be used for classification if a pipeline architecture is used.

Cognitive Rehabilitation based Personalized Solution for Dementia Patients using Reinforcement Learning
Himashi Rathnayaka (Sri Lanka Institute of Information Technology & SLIIT, Sri Lanka); Malshani Manamendra, Roshni Silva and Chathurika Watawala (Sri Lanka Institute of Information Technology, Sri Lanka)

Dementia is one of the most challenging health problems faced globally with the increase in the ageing population. The estimated current prevalence of dementia is 47.5 million worldwide. This number will nearly double in every 20 years globally. Dementia is basically, a syndrome which cannot be cured by medicine, but non-pharmacological therapy can be used to treat Dementia patients, this is known as Cognitive Rehabilitation Therapy. According to the recommendations of the doctors, the use of a brain training application could be better than traditional approaches. There are number of Brain training mobile applications in the world that could be useful in improving human concentration, attention and all sorts of brain activities but there isn't any customized software solution that has games or activities. Patients can be in different stages of Dementia. So, for better cognitive rehabilitation they need the personalized therapies with the games and activities. Accordingly, developing this application is an actual global requirement for dementia patients. The world is evolving with new technologies and this application includes the mind games based on such technologies as Reinforcement Learning which predict the next level for patients based on user behavior. And there are some activities by using speech to text communication as well. Patients, caregivers and doctors can view the score and the progress reports. All the games have designed along with the supervision and recommendation from a Consultant Psychiatrist in Sri Lanka. The main objective is to help the Dementia patients in cognitive rehabilitation to improve the quality of life with best suited personalized games and activities.

Model-Based Systems Engineering

Analysis of software tools for model-based Generic Systems Engineering for organizations based on e-DeCoDe
Marian Mistler, Nadine Schlueter and Manuel Löwer (University of Wuppertal, Germany)

To enable Systems Engineering in interdisciplinary teams adequately, suitable software tools are needed to master the complexity of system modeling within the problem-solving process respectively project management. However, since there are many different approaches for Systems Engineering, this paper considers Generic Systems Engineering (GSE) as a generally valid and proven approach. Furthermore, Systems Engineering can be applied to many different objects. For this purpose, the paper focuses on organization systems. This is due to the fact that the increasingly dynamic markets generate new or changing requirements that affect not only the production and development of technical products, but also the business processes in companies. This implicates, for instance, the infrastructure and the interfaces of business processes, the identification of responsible persons respectively roles, and moreover, the traceability of the information flow between persons and IT systems within the business processes. In order to manage the vast complexity of organizational structures in system modeling, the enhanced Demand Compliant Design (e-DeCoDe) approach is considered as an implicit part of Generic Systems Engineering. Hence, in this paper, we analyze, evaluate, and discuss different software tools and examine their suitability to ensure the model-based development of complex organizational systems using the Generic Systems Engineering and enhanced Demand Compliant Design approach.

A Novel Approach to Behavior Design for Model Based Systems Engineering Application Using Design Structure Matrix
Aditya Akundi (University of Texas at Rio Grande Valley, USA); Tzu-Liang (Bill) Tseng (University of Texas at El Paso, USA); Carmen Almeraz and Rocio Lopez-Terrazas (The University of Texas at El Paso, USA); Hebin Luan (Naval Air Warfare Center Aircraft Division, USA)

Model-Based Systems Engineering (MBSE) is the formalized application of modeling to support various system evolving stages starting from the conceptual design phase to all the life cycle phases that follow. To facilitate in an efficient system behavior design process, in this paper, a Design Structure Matrix (DSM) based approach is developed and illustrated for determining the operational sequence of activities relevant to requirements of the system and in identifying the concurrent activities as well. A triangularization algorithm method is extended especially for application on activity diagrams to determine knowledge activities in an interaction graph to identify groups of activities and arrange them concurrently. The findings through the DSM based approach are validated by a system engineering expert and are implemented to construct the MBSE activity diagram to facilitate an enhanced behavior design of the system. This paper illustrates the use of Design Structure Matrix to facilitate modeling interdependencies between activities and the approach to aggregate the resulted sequential and concurrent activities with the activity diagram, applied to a case study of Execute Hohmann Transfer based on DellSat-77 Satellite System. In addition, the potentials benefits of using a Design Structure Matrix methodology for assisting Model-Based Systems Engineering activities for enhanced systems behavior design are portrayed.

Identifying the Thematic Trends of Model Based Systems Engineering in Manufacturing and Production Engineering Domains

Aditya Akundi (University of Texas at Rio Grande Valley, USA); Viviana Lopez (University of Texas Rio Grande Valley, USA); Tzu-Liang (Bill) Tseng (University of Texas at El Paso, USA)

Manufacturing and production systems have become increasingly complex in the past decade to meet the competitive demand in a growing industry. As these systems grow in complexity and flexibility, there is a need for efficient management and analysis of these systems. Model-based systems engineering (MBSE) addresses the complexity inherent with systems development with a model-centric approach that supported tailored-modeling languages, methods, and tools. This paper identifies the thematic evolution and trends and relationships found in the use and application of MBSE in the manufacturing and production engineering domain. A collection of 471 published articles from the Institute of Electrical and Electronics Engineers (IEEE) and Science Direct over the past decade were used for the analysis using text mining techniques. Due to the limitation on the access to full-text information of all the articles identified, only abstracts were considered for analysis. This effort helps the researchers across the domain to explore the reason behind and understand the change of the thematic perspectives of MBSE application over the last decade. In addition, the finding of the growing interest in addressing the aspects of complexity and systems requirements, and on the aspects of the use of MBSE for identifying and addressing the challenges related to Cyber-Physical Systems, help in paving a path for future research.

Towards a combination of MARTE and ECOA

Mathieu Muzellec and Paul Vivot (ISAE-SUPAERO, Université de Toulouse, France); Rob Vingerhoeds and Pierre de Saqui - Sannes (ISAE-SUPAERO, France)

Through the definition of a metamodel, the ECOA (European Component Oriented Architecture) open standard offers a development framework for complex avionic systems software. Its purpose is to create and maintain architectures to achieve interoperability, sustainability and portability at both functional and software interface level.

However, being a metamodel, ECOA only offers an abstract syntax and theoretical concepts to develop software and their interfaces. It therefore suffers from a lack of modeling language, tools and methods enabling real-time analysis during the development process of software. Combining the rigour of the ECOA metamodel with the potential of model-based analysis would not only allow a reduction in development time of complex software-based systems but also help improving system optimality with respect to hard real-time requirements.

Translation of ECOA concepts into a formally defined and tooled modeling language is thus an avenue to explore. This paper advocates for using the UML real-time profile MARTE (Modeling and Analysis of Real-Time and Embedded systems) as it offers both a concrete syntax to complete the ECOA metamodel as well as a modeling method thanks to its own metamodel.

Results of a preliminary study are presented both in terms of ECOA to MARTE translation and perspectives for real-time analysis of models.

A Model-Based Approach to Enable a Safety Analysis of Software Toolchains
Stephan Baumgart (Volvo Autonomous Solutions, Mälardalen University, Sweden); Yin Chen (ABB, Sweden); Rasmus Hamren (Malardalen University, Sweden)

The increasing use of embedded systems to provide new functionality and customer experience requires developing the embedded systems carefully. Functional safety standards like IEC 61058 or ISO 26262 provide methods and processes to avoid systematic failures for the software and random failures for the electric hardware. Developing software requires utilizing various software tools like editors, code checkers, or compilers. One task in developing safety-critical products is to analyze if the applied tools can introduce failures into the final product. Todays functional safety standards consider only single software tools for analysis and providing requirements throughout the standards. In industry, we can observe a trend towards supporting product lines, where a common configurable platform is developed to support a range of different products. Developing this platform and supporting variability, a toolchain is created where software tools are glued together using scripts to support product lines and to automatically generating compiled code. It is not straight forward supported by the current functional safety standards. In this paper, we discuss how software tools need to support functional safety and show the limitations by providing an industrial case. We provide a model-based approach to describe a toolchain and show its application to an industrial case. In order to analyze potential failures in the toolchain, we utilize a HAZOP method and show its application.

A Model-Driven Framework for Security Labs using Blockchain Methodology
Moneeb Abbas (NUST, Pakistan); Muhammad Rashid (Umm Al-Qura University, Saudi Arabia); Farooque Azam (CEME, National University of Sciences and Technology (NUST), Pakistan); Yawar Rashid (NUST, Pakistan); Muhammad Waseem Anwar (National University of Sciences and Technology (NUST), Pakistan); Maryum Hamdani (MUST, Pakistan)

Blockchain technology is the need of an hour for ensuring security and data privacy. The modern technological trends require prompt automation and rapid implementation however many security labs developers try to implement Blockchain technology in a traditional way. Since Blockchain is an emerging technology and very limited tools and documentation are available, therefore traditional code centric implementation of Blockchain is very challenging for programmers and developers due to inherent complexities. To overcome these challenges, in this article, a novel and efficient framework is proposed that is based on the Model-Driven Architecture (MDA). Particularly, a Meta-model (M2 level Ecore Model) is defined that contains the concepts pertaining to Blockchain technology. As part of tool support a tree editor (developed using Eclipse Modeling Framework) and a Sirius based graphical modeling tool with drag drop palette have been provided. Both the tree editor and Sirius tool are distributable via Eclipse based plugin. Tree editor and Sirius tool allows modeling and visualization of simple and complex Blockchain based scenarios for security labs in a very user-friendly manner. A Model to Text (M2T) transformation code has also been written using Acceleo language that transforms the modeled scenarios into java code for Blockchain application in security lab. Validity of the proposed framework has been demonstrated via case study. The results prove that our framework can be reliably used and further extended for automation and development of Blockchain based application for security labs with simplicity using abstraction-based approach of MDA.

A Model-Driven Framework for the Prevention of DoS Attacks in Software Defined Networking (SDN)

Muhammad Usman Farooq (NUST, Pakistan); Muhammad Rashid (Umm Al-Qura University, Saudi Arabia); Farooque Azam (CEME, National University of Sciences and Technology (NUST), Pakistan); Yawar Rashid (NUST, Pakistan); Muhammad Waseem Anwar (National University of Sciences and Technology (NUST), Pakistan); Zohaib Shahid (GCU, Faisalabad, Pakistan)

Security is a key component of the network. Software Defined Networking (SDN) is a refined form of traditional network management system. It is a new encouraging approach to design-build and manage networks. SDN decouples control plane (software-based router) and data plane (software-based switch), hence it is programmable. Consequently, it facilitates implementation of security based applications for the prevention of DOS attacks. Various solutions have been proposed by researches for handling of DOS attacks in SDN. However, these solutions are very limited in scope, complex, time consuming and change resistant. In this article, we have proposed a novel model driven framework i.e. MDAP (Model Based DOS Attacks Prevention) Framework. Particularly, a meta model is proposed. As tool support, a tree editor and a Sirius based graphical modeling tool with drag drop palette have been developed in Oboe designer community edition. The tool support allows modeling and visualization of simple and complex network topology scenarios. A Model to Text transformation engine has also been made part of framework that generates java code for the Floodlight SDN controller from the modeled scenario. The validity of proposed framework has been demonstrated via case study. The results prove that the proposed framework can effectively handle DOS attacks in SDN with simplicity as per the true essence of MDSE and can be reliably used for the automation of security based applications in order to deny DOS attacks in SDN

A Model Based Neurorehabilitation (MBN) Framework using Kinect

Zaeem Anwaar (NUST, Pakistan); Muhammad Rashid (Umm Al-Qura University, Saudi Arabia); Farooque Azam (CEME, National University of Sciences and Technology (NUST), Pakistan); Muhammad Waseem Anwar (National University of Sciences and Technology (NUST), Pakistan); Yawar Rashid (NUST, Pakistan); Maryum Hamdani (MUST, Pakistan)

Neurological disorders are frequently reported across the world. Patients affected with neurological disorders requires a definite rehabilitation. Various speech and auditory rehabilitation systems have been developed over the period and reported in literature as well. However, modern technological trends require prompt development of complex systems with simplicity. Model Driven Architecture (MDA) has served the purpose for variety of domains and the area of Neurorehabilitation also requires exploration in the context of MDA. This article introduces an MBN (Model-Based Neurorehabilitation) framework. It consists of a meta-model, tree editor, Sirius based graphical modeling tool with drag and drop palette and a model to text transformation engine that transforms the modeled scenario into java code. The framework has the capability to assign various activities like physiotherapy sessions for patients having neuro disorders using Kinect Sensor V2. Currently, our Sirius based graphical modeling tool allows modeling and visualization of various activities that are assigned to patients in order to overcome a specific disorder. The validity of proposed framework is demonstrated via case study by assigning activities using our graphical modeling tool and generating java code from the modeled scenario. The results from the case study prove that our framework is very effective and capable of modeling and visualizing activities successfully.

Model-Based Systems Engineering Applied to the Detection and Correction of Object Slippage within a Dexterous Robotic Hand
Charles A Meehan III and John S. Baras (University of Maryland, USA)

Slip detection and correction plays a very important role in robotic manipulation tasks, and it has long been a challenging problem in the robotic community. Further, the advantage of using systems engineering tools and framework to approach a solution and/or modeling of robotic tasks is not often pursued. In this paper, we use Model-Based Systems Engineering techniques to verify system requirements and validate stakeholder requirements for the problem of detecting and correcting for object slippage within a dexterous five-fingered robotic hand. We will discuss how the work accomplished in our laboratory was transferred to a simulated environment and how this simulated environment built-in CoppeliaSim was connected to a systems engineering software, Cameo Systems Modeler. Measures of effectiveness were created from the stakeholder requirements for the slippage problem which allowed us to validate the robotic simulation that was built. Structural diagrams of the robotic system and environment were built along with behavioral diagrams of the simulation. Further, we used the connection of Cameo Systems Modeler and CoppeliaSim to track the measures of effectiveness for our robotic task which provided us with a complete systems engineering framework for the problem from the requirements phase through the implementation phase. Our main goal is to show the advantages of following a systems engineering framework to complete a robotic task through the connection of Cameo Systems Modeler and CoppeliaSim.

MBSE and MDAO for Early Validation of Design Decisions: a Bibliography Survey
Jean-Charles Chaudemar and Pierre de Saqui - Sannes (ISAE-SUPAERO, France)

Switching from document-centric engineering to Model Based Systems Engineering (MBSE), Systems Engineering (SE) has significantly evolved in terms of standard practices for the design of complex, interdisciplinary systems. MBSE consists in a top-down, model based approach to describe the entire system focusing on different points of view that cover at least structural and behavioral descriptions. Over the past decade, the need to perform an engineering analysis in the early steps of the system's life cycle has opened avenues for joint use of MBSE and Multidisciplinary Design Analysis and Optimization (MDAO). MDAO is fully dedicated to Analysis and Optimization: the model is restricted to a single aspect of the system that is described in details in a formal language that will be the input of the associated computing tool. This paper surveys and categorizes MBSE and MDAO approaches for better understanding of how MBSE and MDAO can be associated in a systems engineering project. Lessons learned from this literature survey will be used in the framework of French project Concorde project. One major expected achievement of the project is to design and implement a methodology to populate parts of the MDAO modeling approach directly from the MBSE one, applied to a UAV case study.

Requirements for a System Model in the Context of Digital Engineering
Ronald Giachetti and Warren K. Vaneman (Naval Postgraduate School, USA)

The vision of achieving digital engineering in the US Department of Defense has instigated work on defining the information content and structure of the system model. However, few seem to have asked what are the requirements for the system model? In this paper, we use a requirements process to elicit and define the requirements for the system mode. The system model is a digital artifact containing descriptions of all the essential objects, their properties, and the relationships between them for the system-of-interest (SoI). The paper describes the context of the system model in relationships to the other components of model-based systems engineering (MBSE) consisting of a modeling language, schema, model-based process, presentation framework, MBSE tools, and knowledgeable workforce. The paper describes how these components interact to provide effective MBSE. Requirements are stated for each component. The paper additionally derives information requirements for the system model according to the systems engineering process's information needs by examining the inputs and outputs of each activity in the systems engineering process. Lastly, the paper derives the quality characteristics for the system model from the literature on ontologies, modeling languages, and semiotics. The result is a set of requirements for the system model to support MBSE and the digital thread.

Integration of Constraint Programming and Model-Based Approach for System Synthesis
Pierre-Alain Yvars (SupMéca QUARTZ EA7393, France); Laurent Zimmer (Dassaut Aviation, France)

Most of the work in the field of Model-Based System Engineering for the design of technical systems consists of implementing solution-oriented approaches. Several system modeling languages are available to represent fully defined systems from several points of view. It is also possible to link these descriptions with simulation or analysis tools to evaluate the solutions thus described. After having studied the limits of this way of designing system, we propose in this paper an approach oriented to the description of the design problem to be solved, through an adapted formalism called DEPS. This formalism allows a model-based approach for architecture and system synthesis. DEPS (Design Problem Specification) addresses problems of sizing, configuration, resource allocation and more generally of architecture generation or synthesis encountered in system design. The systems considered can be physical systems, software-intensive systems or mixed systems (embedded, mechatronical, cyber-physical). This language combines structural modeling features specific to object-oriented languages with problem specification features from constraint programming. We also present an integrated approach through the DEPS Studio environment, allowing DEPS modeling, model compilation and solving using an integrated constraint programming solver. This integration allows, among other things, the development and the debugging of models directly in DEPS rather than in the language of an external solver. The approach is illustrated on a simple case of electrical system synthesis.

Systems Engineering Description: Advanced Quantitative Precipitation Information Behavioral Responses
William M Brooks and V. Chandrasekar (Colorado State University, USA); Greg Pratt (NOAA Global Systems Laboratory, USA); Rob Cifelli (NOAA Earth Systems Research Laboratory, USA)

Atmospheric rivers (AR) contribute a significant portion of the precipitation for the United States' west coast. Flooding events caused by ARs can create millions of dollars in damages. Identifying probable ARs and early warning of potential flooding events can provide state and local agencies the time to prepare for such events. The Bay Area Advanced Quantitative Precipitation Information (AQPI) system links users with varied meteorological data ranging from weather radar observations, short term forecasts (Nowcast), 12-hour forecasts, and coastal inundation modeling data. The range of data types presents an opportunity for proactive responses by the users; however, it also presents the challenge of ensuring the correct data is available to the appropriate user. Through Model Based Systems Engineering (MBSE) Behavioral Analysis, the AQPI team analyzes the appropriate requirements for each of the different types of AQPI users. MBSE behavioral analysis leads to the development of a system that services the broad user community's needs while giving each user group a specific interface tailored for them. This engineering approach also allows for the separation of the processing and weather model execution from the user interface. This separation allows for development and advancements in processing without being tied to the user interfaces.

A generative Approach for creating Eclipse Sirius Editors for generic Systems
Francesco Bedini (Technische Universität Ilmenau, Germany); Ralph Maschotta (Ilmenau University of Technology, Germany); Armin Zimmermann (Ilmenau University of Technology & Systems and Software Engineering, Germany)

Model-Driven Engineering (MDE) is getting more and more important for modeling, analyzing, and simulating complicated systems. It can also be used for both documenting and generating source code, which is less error-prone than a manually written one. For defining a model, it is common to have a graphical representation that can be edited through an editor. Creating such an editor for a given domain may be a difficult task for first-time users and a tedious, repetitive, and error-prone task for experienced ones. This paper introduces a new automated flow to ease the creation of ready-to-use Sirius editors based on a model, graphically defined by the domain experts, which describe their domains' structure. We provide different model transformations to generate the required artifacts to obtain a fully-fledged Sirius editor based on a generated domain metamodel. The generated editor can then be distributed as an Eclipse application or as a collaborative web application. Thanks to this generative approach, it is possible to reduce the cost of refactoring the domain's model in successive iterations, as only the final models need to be updated to conform to the latest format. At the same time, the editor gets generated and hence updated automatically at practically no cost.

Malware System Calls Detection Using Transformers
Yue Guan and Naser Ezzati-Jivan (Brock University, Canada)

Anomalous detection is an important problem that has been researched from diverse perspectives and within various application domains. Many anomaly detection techniques have been developed specifically for certain application areas, while others are generic. There are several challenges in this problem like data collections due to the inherent datasets imbalance, which is caused by systems' reliability requirements making the occurrence of an anomaly a rare phenomenon. Therefore, only a small percentage of available datasets captures the anomaly, which brings in the second challenge, model selection, and a specific approach for detecting an anomaly. While much research has been concentrated on the data collection part and statistical techniques, this paper is devoted to a multi-module system call anomalies detection technique, which is based on using state of techniques to solve this problem. The proposed deep learning model based on Long Short Term Memory(LSTM) and attention using transformers can learn a sequence of a system call to classify the malicious process in the system.

The paper is structured as follows. Section 2 discusses related work. Section 3 discusses various data collection and process techniques and presents the data collection method we used that is created by other researchers. Section 4 describes the feature pre-processing and anomaly detection using the hybrid model in detail. Section 5 shows experiments and results and the last section reviews our work and makes a conclusion.

Providing designers with automated decision making within SySML models to promote efficient model-based system design
Mara Nikolaidou, Christos Kotronis and Anargyros Tsadimas (Harokopio University of Athens, Greece)

Dealing with complexity is a key challenge of designing high-quality systems of systems. This is exactly where model-based system design (MBSD) comes into play. Employing MBSD the system model can be ``an integrating framework for system development, since it provides a consistent source of the system specification, design, analysis and verification information''. Note that the system model itself comprises different diagrams, each one modeling different views of the system, i.e. its structure, the relationships between system components and requirements, as well as the dynamic behavior of the system.

Such a process can be implemented using the Systems Modeling Language (SysML).

Though SysML has been proven to be expressive enough to model complex systems with heterogeneous components and provides the necessary flexibility for tuning or extending native constructs using the profile mechanism, it may not support itself all design activities, as for example simulation to explore the performance of a possible design solution. This limitation has led to numerous approaches to integrate SysML models with external tools more appropriate for specific activities, mainly analytical models to explore performance.

In this work, we follow this rationale, focusing on providing the system designer with additional functionality integrating decision support capabilities within SysML system models. Requirements and basic system components are transformed into a decision making model in an external decision making tool to explore alternative design decisions and present them to the system designer within the SysML system model.

The proposed approach has beed applied in the design of a remote patient monitoring system.

Modeling and Simulation

Maintaining the Consistency of SysML Model Exports to XML Metadata Interchange (XMI)
Holly Handley, Wael Khallouli and Jingwei Huang (Old Dominion University, USA); William Edmonson and Nadew Kibret (North Carolina A&T State University, USA)

The System Modeling Language (SysML) is a visual modeling language that can be used to describe the structure and behavior of a system. Modeling tools can be used to capture the variety of diagrams and maintain the consistency of elements across the different structural and behavioral representations of the system. Current research is investigating using the XML Metadata Interchange (XMI) standard to convert the diagrammatic information captured in SysML into a format that can be used to produce software code that can then be simulated to ensure conformance with system requirements. The XMI standard can be used as an interim format to migrate the content from a diagrammatic representation, where system elements are sorted by the diagram that contains them, to an object approach, where all elements related to an entity reside in a tree structure below that element. This paper presents a method to ensure the consistency of the XMI representation regardless of whether a functional or physical system engineering approach is used for the design process. This has implications in maintaining the consistency of the XMI file when system development is initiated from a high level of abstraction, followed by iterative addition of detail. The goal is to ensure that XMI file maintains an authoritative representation of the modeled system.

Equivalent Circuit Modeling of All-Solid-State Battery by using DC-IR Data
Cisel Aras, Burak Celen and Ahmet Can Erdem (AVL Research and Engineering, Turkey); Markus Dohr and Thyagesh Sivaraman (AVL List GMBH, Hans-List-Platz 1, Austria)

In modern Battery Management Systems (BMSs), it is significant to obtain an accurate battery model to estimate the states of the battery such as State of Charge (SoC), State of Health (SoH), State of Power (SoP), State of Safety (SoS) etc. Traditional lithium-ion batteries (LIBs) have some drawbacks in terms of safety and energy density. To overcome these drawbacks, all-solid-state batteries (ASSBs) are being developed as an alternative solution for conventional lithium-ion batteries. The focus of this study is on all-solid-state batteries and their modeling based on the equivalent circuit model. On the other hand, the modeling of a cell needs an immense amount of data and long test duration time. Instead of cell characterization test data, the all-solid-state cell is modeled by using DC internal resistance (DC-IR) information. During this study, two different equivalent circuit models containing series-connected RC pairs with and without ohmic resistance are investigated. In addition, the equivalent circuit model parameters are derived via Genetic Algorithm. Moreover, measured and simulated resistance values are compared with Mean Absolute Error (MAE) criteria for two different equivalent circuit models. Finally, the plausibility of the obtained models are analyzed and compared with experimental Hybrid Pulse Power Characterization (HPPC) test results.

Energy-aware Trajectory Planning Model for Mission-oriented Drone Networks
Ying Li (Colby College, USA)

The high mobility and easy deployment of drone networks encourage people to adopt this type of network for various projects, such as package delivery, systemic assessment, crisis control, border surveillance, etc., after equipped necessary sensors. However, the limited battery capacity largely constrains the operation time of drones. Elaborate and stringent planning is essential to succeed in mission execution energy-efficiently. We propose an energy-aware trajectory planning model for drones to accomplish all tasks in a mission-oriented network energy-efficiently. Our focus in this study is on minimizing the energy spent on travel to save more energy for task execution. In our study, task lengths are not binary, which means that each task takes more than one time-unit to complete, and a drone may execute a portion of a task. To the best of our knowledge, our work is the first to introduce the energy spent on task execution to travel-cost minimization models, considering that both travel and task execution consume the battery power of drones. We also evaluate the performance of the proposed model. We found that the total-traveled distance of drones that follow the trajectories generated by the proposed model is significantly less than that of the drones that employ the strategy proposed in recent work regardless of the task length.

Emphasis on evaluative prerequisites for decisive Software-in-the-Loop (SiL) environments
Kushal Koppa Shivanandaswamy (Robert Bosch Engineering & Business Solutions Pvt Ltd, India)

Recent trends in virtualization has shown significant desideratum, for the simulations to be performed using credible SiL environments. The SiL environment is a plausible approach, which is decisive in verifying the complex control algorithms, embedded into various automotive ECUs. Major challenges would be associated with the approaches, processes, and in manipulation of risks, in the course of development of credible SiL environments. The need for a competent mitigation plan is required, which might postulate a paradigm shift in the software development processes. This is quintessentially required for the development of an effective, reliable and a credible SiL environment. With different approaches and processes, currently, for different SiL environments, created using different tools, from different vendors (like dSPACE, ETAS, Synopsys, Vector etc.), emphasis on the evaluation of standard set of prerequisites is very much necessary. The evaluation provides technical clarity and aids in the process of vECU generation, with significant impact on the implementation of a credible SiL environment. This decisive SiL environment thus enables in verifying & validating the vECU behavior and performance. In this paper, we provide insights on the evaluative prerequisites, considered prior to the creation of SiL environment. The evaluation of these prerequisites are imperative in identifying and selecting the software components and evaluating its available information, integrated as part of vECU. With the help of use-cases, we try to highlight and emphasize on the imperative prerequisites, evaluated and the need for its evaluation, in creating a credible SiL environment.

Modeling and Simulating Federated Databases for early Validation of Federated Searches using the Broker-based SysML Toolbox

Sylvia Melzer and Stefan Thiemann (Universität Hamburg, Germany); Ralf Möller (Universität zu Lübeck, Germany)

In research and cultural institutions as well as in companies, many data are collected and increasingly stored in databases. For example, during the project EDAK (Epigraphische Datenbank zum antiken Kleinasien) the Department for Ancient History at the Universität Hamburg created an epigraphic database of ancient Asia Minor. This database contains a collection of Greek and Latin inscriptions from modern-day Turkey.

For analyzing data, a user usually sends a query to one database and receives an answer. However, it is not always sufficient to use one database only. For example, the fragment AO 29196 is located at the Louvre. The counterpart of this fragment is the fragment KUG 15 which is located in Germany. Indeed, both fragments were found without database federation, but in the future, for analyzing data from different databases it would be desirable to find related data in a FDBS. This example highlights the need to sometimes combine, analyze, and query data from different databases.

Database federation offers a logical centralization of data without the need to change physical implementation of the databases. Thus, the complexity of query execution increases. Users send queries to the FDBS, and then the FDBS forwards queries to each (relevant) database node. The answer to queries vary. The response may be correct, incorrect, or incomplete. To overcome this problem, theoretical foundations have been developed.

Although theories exist for implementing FDBSs, in practice, the implementation of a FDBS is a complex task. When using the currently-existing FDBS such as Denodo, a programmer or engineer still has to develop a congruent overview for querying internal as well as external databases. An FDBS is often expensive to develop. We predict that early validation of federated searches may identify problems which need to be solved before implementation. Therefore, we recommend carrying out a feasibility study before a FDBS is set up.

In this paper we present how to model and simulate federated databases before implementation. The development of database federation for early validation of federated searches is challenging due to the distribution, heterogeneity, and autonomy. In order to support the development, established methods, tools, and languages for modeling, simulating, and validating systems are useful.

Developers are supported in model-based development using the SysML, the modeling and simulation tool Cameo Systems Modeler and the broker-based SysML Toolbox. For modeling and simulation, we use the tool Cameo Systems Modeler and the broker-based SysML Toolbox. In addition, we evaluate our pragmatic approach by feasibility study by means of a prototypical implementation of federated databases.

This paper is structured as follows. First, the databases are briefly described which are used for the feasibility study. Second, the broker-based SysML Toolbox, as an extension of the tool Cameo Systems Modeler, is introduced which contributes in creating communications networks. Third, broker federation is explained, followed by describing the characteristics of federated databases and the challenges providing federated searches. Subsequently the pragmatic approach for modeling and simulating an FDBS with low coding efforts is demonstrated. Afterwards an evaluation for federated searches is presented. Finally, a short conclusion is given.

Role of Affordance, Visual Density and Other HCC Criteria in Designing Virtual Learning Environments to Support STEM Learning for Autistic Students

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This paper discusses the design of Virtual Learning Environments (VLEs) in helping students with autism learn Science and Engineering concepts. The design of the environments was based on information centric principles. Further, human centered computing principles (HCC) was also explored during the development of the VLEs. HCC principles such as affordance, visual density and cognitive load were taken into consideration during the design process. The VLEs were created for middle and high school students. An information-centric model was created to understand the process of designing and building the VLEs. Such information models based on engineering Enterprise Modeling Language (eEML) provided a structural foundation for the design and development of the VLEs. The learning environments were created using various interfaces and immersion levels; these included haptic based interfaces and fully immersive 3D environments. These VLEs introduced students to concepts in assembly and path-planning in the context of NASA's moon mission. Assessment activities were conducted to gain a better understanding of the impact of such VLEs on the learning of science and engineering concepts to middle and high school students. The preliminary results of the assessment activities demonstrated the positive impact of such cyberlearning techniques and environments on the learning of students with autism.

Multi-Objective Heterogeneous Multi-Asset Collection Scheduling Optimization with High-Level Information Fusion

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Surveillance of areas of interest through images acquisition is becoming increasingly essential for intelligence services. Several types of platforms equipped with sensors are used to collect good quality images of the areas to be monitored. The evolution of this field has different levels: some studies are only based on improving the quality of the images acquired through sensors, others on the efficiency of platforms such as satellites, aircraft and vessels which will navigate the areas of interest and yet others are based on the optimization of the trajectory of these platforms. Apart from these, intelligence organizations demonstrate an interest in carrying out such missions by sharing their resources. This paper presents a framework whose main objective is to allow intelligence organizations to carry out their observation missions by pooling their platforms with other organizations having similar or geographically close targets. This framework will use multi-objective optimization algorithms based on genetic to optimize such mission plannings. Research on sensor fusion will be a key point to this paper, researchers have proven that an image resulting from the fusion of two images from different sensors can provide more information compared to original images. Given that the main goal for observation missions is to collect quality imagery, this work will also use High-Level Information Fusion to optimize mission plannings based on image quality and fusion. The results of the experiments not only demonstrate the added value of this framework but also highlight its strengths (through performance metrics) as compared to other similar frameworks.

Energy Consumption Evaluation of LPWAN: A Stochastic Modeling Approach for IoT Systems
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Energy consumption has been a well-known concern on computing systems, and due to the emergence of IoT applications, particular attention has been devoted to network technologies. The energy for a communication transceiver component to send one single bit can be 1500 to 2000 times higher than the energy required to execute a single instruction, and many IoT applications adopt energy-constrained networks, such as low-power wide-area networks (LPWANs).

Thus, mechanisms for assessing energy consumption of the network physical layer for IoT applications are prominent for system design. Despite the importance of assessing the communication transceiver's energy consumption, to the best of our knowledge, just a few works propose models for evaluating LPWAN and WSN transceivers independently of technology with probabilistic packet loss behavior.

This paper presents a modeling approach based on Stochastic Petri nets (SPN) formalism family capable to evaluate the energy consumption for LPWAN and WSN networks, focusing on the communication transceivers and channel with packet loss probabilistic behavior. The proposed models have been validated using Lora physical layer chip with an error of 1.63% to transmit data and 1.33% to receive data. The experimental results show the feasibility of the proposed models to estimate a node and network energy consumption.

A Software Maintenance Methodology: An Approach Applied to Software Aging
Jean Carlos Teixeira de Araujo (Universidade Federal do Agreste de Pernambuco, Brazil); Carlos Melo (UFPE, Brazil); Felipe Oliveira (Federal Rural University of Pernambuco, Brazil); Paulo Pereira (Federal University of Pernambuc, Brazil); Rubens S. Matos, Jr. (Federal Institute of Education, Science, and Technology of Sergipe, Brazil)

The increasing use of computational systems has highlighted concerns about attributes that may influence the quality of service, such as performance, availability, reliability, and maintenance capacity. Failures in the software development process may impact these attributes. Flawed code and overall software misdesign may cause internal errors, leading to system malfunction. Some errors might be identified and fixed during the software testing process. However, other errors may manifest only during the production stage. This is the case of the software aging phenomenon, which is related to the progressive degradation that a software performance or reliability suffers during its operational life. This paper proposes a methodology for software maintenance that is tailored to identify, correct, and mitigate the software aging effects. If the source code can be modified and a new version deployed with minimal impact, thus data from aging detection is used for corrective maintenance, i.e., for fixing the bug the causes the aging effects. If the software cannot be fixed nor its version updated without long system interruption or other bad consequences, then our approach can mitigate the aging effects, in a preventive maintenance to avoid service outages. The proposed methodology is validated through both Stochastic Petri Net (SPN) models and experiments in a controlled environment. The model evaluation considering a hybrid maintenance routine (preventive and corrective) yielded an availability of 99.82%, representing an annual downtime of 15.9 hours. By contrast, the baseline scenario containing only reactive maintenance (i.e., repairing only after failure) had more than 1342 hours of annual downtime - 80 times higher than the proposed approach.

Robotic Systems

Hardware-in-the-loop simulation for embedded prosthesis control
Mohamed Abdelhady and D Simon (Cleveland State University, USA)

Prosthetic assemblies for lower limb amputees are highly engineered and consist of several electromechanical components. The motorized prosthesis control passes multiple test stages to ensure patient safety. The hardware-in-the-loop technique assists reduce test cost and risk factors during the design phase. Currently, the advanced prostheses testing technique considers a biped or uniped robot to conduct preliminary tests for prosthesis prototype. This paper demonstrates using hardware-in-the-loop to mimic control action scenarios in an active prosthetic leg attached with a biped robot. The uniped robotic motion mimics the human hip during a normal walk. Our simulation framework is prepared to validate embedded control hardware and the associated control schemes. Moreover, the simulation used to carry out a comparative assessment for model-based controllers such as computed toque and Soltine and Li approach, and a regressor free approach such as adaptive control based on function approximation technique (FAT). The controller side comprises an embedded single-board computer (SBC) host control scheme and commanding a simulation computer. On the other side, the simulation computer running a multibody model of a robotic setup that mimics hip motion. HIL simulation shows that the adaptive FAT controller has better trackability with less control effort compared to the computed torque and Slotine controller.

VITA1: A UUV Prototype Designed for Operation in Underwater Tunnels and Power Plants
Vitor A. M. Jorge (Instituto Tecnológico de Aeronáutica & FCMC, Brazil); Pedro Daniel de Cerqueira Gava (Instituto Tecnológico de Aeronáutica - ITA, Brazil); Juan R. B. F. Silva, Thais Mancilha, Valdir Vieira, Geraldo Adabo and Cairo L. Nascimento, Jr. (Instituto Tecnológico de Aeronáutica, Brazil)

New technologies have pushed UUV use in the industry where the focus is often on oil and gas applications and high end systems. Operation in broad underwater hydro power plant tunnels where water turbidity is high, make it difficult to orient Observation Class UUVs inside them. Poor sensory orientation inside the tunnel can put the vehicle integrity and operation effectiveness at risk. In this work, we present a compact UUV prototype which is designed for operation in power plant flooded tunnels. The system architecture is described and each subsystem is tested. Experiments present the effectiveness of each subsystem, with focus on the tunnel, discussing each system in the context of future mapping and autonomous operations. We present a system with a set of sensors aiming manual and autonomous navigation: an imaging sonar for forward looking information and navigation; an array of echosounder sensors used to measure the distance between top, bottom and side walls, which complement the forward looking sonar information; a profiling sonar for tunnel cross-section profiling; and a low light camera for close range inspections. Tests with the system are performed in a swimming pool, a lake, and, finally, inside a hydro power plant tunnel, during a four day-trial at Ceran Castro Alves power plant.

A System For P300 Detection Applied To Vehicle Navigation
Riley Magee (Royal Military College of Canada, Canada); Sidney Givigi (Queen's University & Royal Military College of Canada, Canada)

Brain-machine interface (BMI) systems are used to classify biological signals from the brain, such as electroencephalogram (EEG) data, to determine control commands. There are several different signals that can be used for the interface. Among them, one finds the P300 signal. The P300 signal is a potential signal that is passively produced when a user observes, hears or pays attention to a desired stimulus. This signal has been used in conjunction with a graphical user interface (GUI) to allow a person to choose commands from a list of possible actions. Traditionally, the visual stimuli are repeated and averaged to increase classification accuracy, which, in turn, reduces the maximum possible command rate. In order to improve command rate, this paper describes a system wherein feature extraction and classifier training could be tested offline. Then, live testing in a mobile robot steering simulation was carried out. Finally, a live experiment is reported. The features to be used in classification are selected using a genetic algorithm (GA). Using the chosen features, 78.3% signal detection accuracy was achieved for single epochs. Using multiple-epochs to improve classifier performance in simulated and real-world steering experiments we were able to successfully navigate a simple maze while maintaining classifier accuracy (Sim: 79.9 +/- 5.3%, Real: 88.8 +\- 10.1%).

Investigation of Real-Time Task Scheduling on Robot Fleets with Reconfigurable Actuators
Trevor Robin Smith (McMaster University, Canada); Spencer Ploeger and Benjamin M Dyer (University of Guelph, Canada)

Multi-Fleet Scheduling (MFS) is concerned with the issue of assigning tasks to a swarm of mobile robotic agents. In this paper, MFS of tasks using a novel class of mobile agents with reconfigurable modular actuators is proposed and analyzed. MFS is split into two regimes, static and dynamic, where the static regime does not allow real-time reconfiguration of agent actuators. Existing models are compared to the static multi-fleet scheduling (S-MFS) regime, whereas the agents being investigated are capable of using the dynamic multi-fleet scheduling (D-MFS). Solutions to both problems are compared, and it is shown that in the worst case scenario, given some set of agents and tasks available at known start times, D-MFS finds the same optimal schedule as S-MFS, whereas D-MFS can be used to find more optimal solutions in some conditions. It is also shown that D-MFS may not always be optimal depending on the arrival of previously unknown a-periodic tasks, as D-MFS provides the optimal schedule for a specific fleet of robots accomplishing a set of tasks for some scheduling algorithm and cost function. By defining and exploring the D-MFS problem, this work paves the way for future works in task-prediction, efficient large-scale scheduling algorithms, and novel robot manufacturing capabilities.

EKF-SLAM with Autonomous Exploration using a Low Cost Robot

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Autonomous exploration and mapping is one of the main problems of robotics considering its application for many real life problems for military and commercial use. This article proposes a solution, using a low cost robot, based on EKF-SLAM (Extended Kalman Filter) to explore an static and unknown 2D environment composed of walls and cylinders, which are modeled as line segments and circles for the feature-based map built. The proposed solution uses border detection in occupancy grid maps and path planning with the A* search algorithm to generate a safety and feasible paths for exploration of the environment. To implement the proposed solution a differential drive robot was designed and built with the following sensors: a laser scanner, electronic compass and wheel odometry. The robot is equipped with a Raspberry Pi 3 B plus single board computer that communicate via wireless network Wi-Fi with a remote computer responsible for sending motion commands, decision making and building the map. The algorithms developed for the SLAM and autonomous exploration problem's solution were demonstrated in an indoor environment of approximately 41 squared meters. Experimental results showed that the proposed method reached an average of 8.11 cm of error for walls and 4.33 cm for the cylinders.

Sensors Integration and Applications

A Low Cost Modular Radio Tomography System for Bicycle and Vehicle Detection and Classification

Marcus Haferkamp, Benjamin Sliwa and Christian Wietfeld (TU Dortmund University, Germany)

The advancing deployment of ubiquitous Internet of Things (IoT)-powered vehicle detection and classification systems will successively turn the existing road infrastructure into a highly dynamical and interconnected Cyber-physical System (CPS). Though many different sensor systems have been proposed in recent years, these solutions can only meet a subset of requirements, including cost-efficiency, robustness, accuracy, and privacy preservation. This paper provides a highly modular system approach that exploits radio tomography in terms of both attenuation patterns and highly accurate channel information for reliable and robust detection and classification of different types of road users. Hereto, we have exploited WLAN and Ultra Wideband (UWB) transceiver modules providing either Channel State Information (CSI) and Channel Impulse Response (CIR) data, respectively. Since the proposed system utilizes off-the-shelf and power-efficient embedded systems, it allows for a cost-efficient ad-hoc deployment in existing road infrastructures. We have evaluated the performance of the proposed modular radio tomography system for cyclists and other motorized vehicles with an experimental live deployment. In this concern, the evaluation's primary focus has been on the accurate detection of cyclists on a bicycle path. However, we also have conducted preliminary evaluation tests measuring different motorized vehicles using a similar system configuration as for the cyclists. In summary, the system achieves an accuracy of 99% for detecting cyclists and more than 98\% regarding the classification of cyclists and passenger cars.

Performance Quantification and Heart Rate Analysis in A Repeated-trial Simulation-based Training Task

Imali Hettiarachchi, Samer Hanoun and Rakesh Veerabhadrappa (Deakin University, Australia); Dawei Jia and Simon Hosking (Defence Science & Technology Group, Australia); Asim Bhatti (Deakin University, Australia)

In this study, we investigated the relationship between individuals' performance and their heart rate (HR) in a simulation-based training task. Participants were required to monitor a set of unmanned aerial vehicles (UAVs) simulated on a computer monitor, observe fuel levels and refuel within a defined time window. The task was cognitively demanding as it required individuals to be highl y attentive. Participants took part in ten trials while their eye-gaze, HR and galvanic skin response were acquired simultaneously. Based on the retention of task performance in later trials, participants were categorised into two groups, a high performance (HP) group and low performance (LP) group. We found that the HP group showed a higher HR compared to the LP group while performing the task, with a difference of around 7 beats per minute. This finding was verified by participants' responses to a post experiment feedback questionnaires. HP participants with higher HR reported better cognitive engagement compared to the LP participants. The LP group reported higher task difficulty compared to the HP group, which might have caused them to exert low effort leading to less engagement. This was reflected in their lower HR and performance scores, compared to the HP group. A regression analysis between performance scores and HR also indicated that HR could be used as a predictor of performance between individuals with high task engagement.

Using Recurrence Quantification Analysis to Quantify the Physiological Synchrony in Dyadic ECG Data

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

Socio-physiological compliance (SPC) is highly regarded in team settings and has attracted significant interest from science of teams researchers. Linear measures of heart rate variability (HRV) has been widely adopted to observe and analyse SPC by evaluating physiological interconnection between members of collaborating teams. In the recent past, nonlinear measurements such as Recurrent Quantification Analysis (RQA) has gained a significant momentum in the measurement of physical stress experienced by individuals using the electrocardiogram (ECG) recordings. In a team context, however, literature shows variants of RQA such as Cross-RQA and Multivariate-RQA have been commonly employed to analyse behavioural data from accelerometer or eye-tracking recordings, respectively. The current study presents an analysis employing RQA in a team setting using the HRV data derived from ECG recordings. From individuals, RQA is employed to extract nonlinear features of HRV, and the physiological synchrony between cognitively engaging participants is quantified via Pearson's correlation coefficient. Most importantly, the study explores the effectiveness of these nonlinear HRV features as alternate options to asses SPC. In terms of capabilities to distinguish collaborating pairs', the RQA measures; recurrence rate, laminarity, determinism and entropy, were observed to be robust in short-term window lengths and equally sensitive compared to linear features of HRV.

A Cluster-Based and Drop-aware Extension of RPL to Provide Reliability in IoT Applications

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The standardized IPv6 Routing Protocol for Low-power and Lossy Networks (RPL) has enabled efficient communications between thousands of smart devices, sensors, and actuators in a bi-directional, and end-to-end manner, allowing the connection of resource constraint devices in multi-hop IoT infrastructures. RPL is designed to cope with the major challenges of Low-power and Lossy Networks (LLNs), specifically their energy-efficiency. However, RPL is facing with severe congestion and load balancing problems, leading to a low Packet Delivery Ratio (PDR) in the network. For the first time since the declaration of RPL, in this paper we explain that ignoring the specifications of the reception and transmission buffers in heterogeneous networks has caused these unbalanced traffic loads, leading to congestion, and consequently loss of packets in RPL. In order to resolve this problem, this paper introduces CBR-RPL; a light-weight RPL-based routing mechanism, which organizes the nodes into logical clusters and routes the packets through a novel drop-aware Objective Function (OF). The newly defined OF considers the queue occupancy of the nodes transceivers along with their drop rate simultaneously. According to an extensive set of experiments, which have been conducted via the Cooja simulator, it has been observed that the CBR-RPL improves the reliability in terms of PDR by 38.2%, and 75% compared to RPL and QU-RPL, respectively. In addition, CBR-RPL has also improved the amount of energy consumption in the nodes by up to 3× compared to the state-of-the-art, mainly due to imposing fewer control packets to the network.

Socio-Technical Systems

A Transdisciplinary Socio-Technical Systems Approach: Wireless Solutions for the Digital Divide
Shamsnaz V Bhada (Worcester Polytechnic Instiute, USA); Casey Canfield (Missouri University of Science & Technology, USA); Alexander M. Wyglinski (Worcester Polytechnic Institute, USA)

The digital divide remains a problem in the United States as well as the rest of the world and has intensified during the 2020 COVID pandemic. The World Bank predicts that the future of economic development will depend on 5G, recognizing broadband as an essential service for individuals, businesses, and governments. The World Economic Forum recommends transdisciplinary systems approaches requesting collaboration across wireless companies, government, and communities to resolve this challenge. Researchers suggest that a 10% increase in fixed broadband adoption is associated with a 1-3% increase in per capita gross domestic product (GDP), increased incomes, and reduced unemployment. Beyond economic development, broadband access can improve healthcare outcomes, educational attainment, and access to emergency services. According to the 2019 FCC Broadband Deployment report, "over 26% of Americans in rural areas and 32% of Americans in Tribal lands lack coverage from fixed terrestrial connections to the FCC defined broadband speeds of 25 Mbps / 3 Mbps, as compared to only 1.7% of Americans in urban areas." Over the course of 5 years, access in urban areas nears 100% while rural access has had statistically insignificant change. This is largely driven by the poor economics for infrastructure investment in rural areas that have low population density. Unfortunately, the focus on infrastructure build-out suffers from insufficient analytical and experimental research to determine the best technologies and policies to enhance utilization and quality of service in rural communities. A recent pilot in Missouri suggests that up to 38% of rural census blocks are incorrectly reported as served in the FCC data, which has major implications for funding allocation.

To bridge this digital divide, this paper proposes a model to explore transdisciplinary systems approaches by bringing together stakeholders from the wireless, policy, and systems engineering communities to devise transformative and high-impact solutions. The wireless community possesses extensive knowledge on how to devise systems capable of delivering significant amounts of bandwidth and achieve maximum user capacity, especially for urban and suburban areas. However, there does not exist sufficient understanding with respect to the unique characteristics and limitations of the rural operating environment, which sometimes contradict the objectives for urban/suburban wireless broadband connectivity. At the same time, the rural broadband policy community understands the needs, requirements, and conditions of the rural environment but do not possess a deep understanding of the latest capabilities of today's wireless technologies. The systems engineering community is capable of bridging this gap between the two communities such that today's spectrum regulations and latest wireless communication systems defined by standards such as 4G/5G can explore potential overlooked opportunities to deliver wireless broadband to rural populations. This paper introduces the transdisciplinary systems approach to model a solution with wireless, policy, and community aspects to achieve sustainable long term solutions to a persistent technology-community-policy problem.

How emoji and word embedding helps to unveil emotional transitions from social media interactions

Moeen Mostafavi and Michael Porter (University of Virginia, USA)

Social media is a commonly used way of communication; however, inferring an individual's emotions during social media interactions is relatively unknown. Text mining techniques can reveal the affective meaning of a text, but another social interaction model is required to understand how emotions change during a social media interaction. Knowing the individual's feelings can be critical when machines such as chatbots interact with humans. We use Affect Control Theory (ACT) to model an individual's emotional transition in this process. ACT is a formal theory of culture that attempts to explain social behavior. ACT predictions about interaction dynamics are dependent on initial cultural sentiments, which are indexed in the affective dictionaries. Using emoji and word embedding, we explain how we can extend affective dictionaries to include the most commonly used words and emojis in daily applications. Then we discuss how to improve the interpretation of emotions in social media interactions using extended affective dictionaries.

The contribution of this project will be in two primary areas: (1) Developing extended affective dictionaries include emojis in their embeddings. (2) Develop an algorithmic way to use emoji and word embedding for emotion change modeling in social media interactions.

A Tale of Two Metrics: Polling and Financial Contributions as a Measure of Performance

Moeen Mostafavi, Michael Porter, Yichen Jiang, Maria Phillips and Paul Freedman (University of Virginia, USA)

Campaign analysis is an integral part of American democracy and has many complexities in its dynamics. Experts have long sought to understand these dynamics using a variety of techniques. This study applies a modeling technique previously used in health sciences research to better understand the relationship between two key components of election campaigns: campaign finance and standing in the polls. We use joinpoint regression modeling to explore the impact of one component on another, as well as their relationship to campaign performance. This study demonstrates the value of joinpoint regression in political campaign analysis and it represents a crossover of this technique into the political domain building a foundation for continued exploration and use of this method.

The 2020 Democratic primary season provides an unusually useful opportunity to study the relationship between fundraising and poll performance. With more than two dozen candidates vying for the nomination, there is a wealth of data to analyze. This study explores two components of campaign performance in the context of the 2020 Democratic primaries. We examine the timing of increased campaign donations and changes in poll position, asking which comes first, and under what conditions? Can one be used to predict changes in the other? And does the relationship between polling and money look the same at different points in the campaigns or even across different candidates?

Toward a Better Integration of AI into SE Methods: Setting a Research Agenda
Steven Doskey (MITRE Corporation, USA); Philip Barry (The MITRE Corporation & George Mason University, USA); Andreas Tolk (Old Dominion University, USA)

The growing prevalence of volatility, uncertainty, complexity, and ambiguity expected in the environment and systems of the future will require systems engineers to also address those same attributes to a greater degree than is currently possible by humans alone. They will require new System Engineering methods and tools to realize solutions that meet design goals for resiliency, robustness, and efficiency across a wider array of states. Recent advances in Artificial Intelligence techniques hold the promise for creating such tools that help explore the solution space in a more efficient way and help identify hidden sources of risks and their likelihoods. While general AI has yet to be realized, AI advances to date, if embraced by systems engineers can also enable a technological shift from development of discrete 'one-off' systems to one that involves a more generative compositional approach for delivering capabilities. Under this approach changes in requirements trigger a rapid reconfiguration of function-enabling system components rather than a change management controlled traditional top-down development of system components. Transitioning to this new focus of modern sociotechnical systems design also requires fundamental changes to the systems engineering development methodologies. To promote wider community discussions in this regard, the authors propose a research agenda guide with the goal of accelerating transition towards a new AI for Systems Engineering (AI4SE) paradigm.

System Architecture

Towards System Level Knowledge Representation For Complexity
Paola Di Maio (Center for Systems, Knowledge Representation and Neuroscience)

To understand and learn from high level cognitive functions such as intelligent behaviour, in computer science, AI and in science as a whole it is necessary to capture and process increasing degrees of complexity.

The design and engineering of Intelligent Systems leverages converging techniques from Artificial Intelligence, Knowledge Representation and Cognitive Architectures, resulting in increasingly complex and diverse architectures that require suitably sophisticated conceptual structures to be modelled and explained.

Depending on the cognitive makeup of those who observe it, and the knowledge available, complexity can be traversed following a variety of paths and solutions. In other cases however, complexity cannot be broken down without losing essential information about the system as a whole.

Addressing a need to develop cognitive artefacts, methods and techniques to capture and represent complexity, this paper proposes a conceptual structure that aims to create a continuum between cognitive engineering and KR, with the aim to capture complex technical and socio technical systems dimensions. The paper presents considerations about cognitive aspects of complex systems theory and practice and Anticipating a convergence between cognitive architectures and AI, a system level knowledge representation artefact is proposed that synthesizes aspects of complexity deriving from combining technical and socio technical systems dimensions from perceptual to systemic.

Transfer Learning on the Edge Networks
Deepak Kaur Saggu and Akramul Azim (Ontario Tech University, Canada)

Transfer learning focuses on using extensive labeled data samples in the source domain to resolve a different yet related task for the target domain, even when there is no similarity among the training and testing problem's datasets and distribution of features. This paper will discourse the implementation of the transfer learning model on edge networks to improve the performance factors and communication delay times within different servers. Any extensive system working with embedded systems is considered a high-performance system. An embedded system aims to perform some specific tasks based on the microprocessors, works on low resources and have less power consumption. An embedded system has a functional mapping, and various environment states to generate significant results. For the edge networks, the description of tasks and the dynamics of outer environment is crucial. For further clarification, we developed the transfer learning model. We experimented it on the embedded system using edge device (edge networks) and the local system to compare the time latency of the transfer learning model's execution. As a result, we concluded that the transfer learning model works effectively and gives us decent accuracy. Implementing a transfer learning model on edge networks is better than implementing on a local system in terms of cost, performance and efficiency.

diaLogic: Interaction-Focused Speaker Diarization
Ryan Duke and Alex Doboli (Stony Brook University, USA)

diaLogic is a user-friendly Python program which performs social interaction classification through speaker diarization. The main libraries used include Python's PyQt5 and Keras APIs, Matplotlib, and the computational R language. Speaker diarization is achieved with high consistency due to a simple four-layer convolutional neural network (CNN) trained on the Librispeech ASR corpus. Speaker interactions are modeled through a custom R language script. The data generated by the program allows the characterization of speaker traits within social experiments. Group leaders, followers, and level of speaker contribution can be characterized. These traits can be used to determine overall group performance, as well as the performance of individuals. The interface is designed to be simplistic and intuitive, which allows easy operation by non-engineers. This design consideration allows program operation with minimal training for users in the social sciences disciplines. The program is designed with a modular backend, which is invisible to the user of the program. The backend allows easy expansion through modular algorithms. For future iterations of the program, speaker interaction data collection will be fully automated through machine learning and/or logical constructs. The integration of voice-based emotion recognition will be the next phase for this program. Overall, the diaLogic program is the central workspace for social interaction characterization.

Enabling the Digital Transformation of the Workforce: A Digital Engineering Competency Framework
Adam Baker (Georgia Institute of Technology, USA); Kara M Pepe (Stevens Institute of Technology & Systems Engineering Research Center, USA); Nicole Hutchison and Mark R Blackburn (Stevens Institute of Technology, USA); Rabia Khan (Naval Postgraduate School, USA); Russell Peak (Georgia Institute of Technology, USA); Jon Wade (University of California San Diego, USA); Clifford Whitcomb (Naval Postgraduate School, USA)

This paper describes the goals, approaches, initial results, and preliminary implementation of WRT-1006, a multi-phase research task within the Systems Engineering Research Center (SERC). Evidence across the Services and industry has affirmed digital engineering is a critical practice necessary to support acquisition in an environment of increasing global challenges, dynamic threats, rapidly evolving technologies, and increasing life expectancy of our systems currently in operation. Digital engineering updates the systems engineering practices to take full advantage of computational technology, modeling, data analytics, and data sciences. The Department of Defense's vision for digital engineering is to modernize how the Department designs, develops, delivers, operates, and sustains systems, while continuing to practice systems engineering efficiently and effectively. Digital transformation is fundamentally changing the way acquisition and engineering are performed across a wide range of government agencies, industries, and academia. As the Department of Defense (DoD) transitions to digital engineering, there is a need to develop and maintain an acquisition workforce and culture that is literate in model-based engineering, competent in digital engineering models, methods, processes, tools, and understands digital artifacts across the acquisition lifecycle. One of the critical steps that was identified to enable this digital transformation is the development of a competency model that can be used to modernize the workforce.

This paper outlines the results after completion of Phase 1 of WRT-1006, which concluded in the initial release of the Digital Engineering Competency Framework (DECF) by SERC, and the initial Phase 2 efforts of implementing the framework as a benchmark for the content of a digital engineering training curriculum. The purpose of the DECF is to provide clear guidance for the DoD acquisition workforce, in particular the engineering acquisition workforce, through clearly defined competencies that illuminate the knowledge, skills, abilities, and behaviors required for digital engineering professionals. The approach taken to develop the DECF drew from existing competency models in fields neighboring digital engineering and from the feedback of experienced practicing digital engineering community.

The initial version of the DECF v1.0 has been released as a key WRT-1006 phase 1 result with confidence in the maturity of the structure and general content. The overarching structure of the DECF v1.0 consists of competency areas, proficiency levels within the competency, and constituting knowledge, skills, abilities, and behaviors (KSABs). Now that this benchmark is established, the second phase of our project involves the comparison of the DECF to the existing Defense Acquisition University (DAU) curriculum to determine what elements of such existing curriculum already support the competencies in the model. This is a bidirectional analysis that will both identify gaps in the training curriculum and potentially identify curriculum content that should be incorporated into the competency model. Although this project is specifically applying the DECF to the acquisition process, the model has applications in any area that will implement Digital Engineering initiatives. Furthermore, this framework has additional use cases that will be explored further including hiring for Digital Engineering positions and ensuring the current work force has the necessary skillsets to adequately implement a digital transformation.

Distributed Ledgers in Developing Large-Scale Integrated Systems
Michael F Marchini (Villanova University & Lockheed Martin, USA)

Large-scale development and maintenance projects involve numerous dependencies across multiple disparate organizations, and these projects are subject to contractual stipulations, customer requirements, stakeholder expectations, and compliance/regulatory issues. Because these dependencies and constraints can change over time, mechanisms must exist to absorb, propagate, and implement perturbations to the original scope of work. Such mechanisms are generally human-oriented, involving significant effort to confirm successful modification while avoiding systemic regression. Distributed Ledger Technology alleviates concerns of regression while providing cost-effective, actionable business insight during the development of large-scale, integrated systems. Fine-grained insights benefit all parties involved in the system's development, allowing for the incorporation of necessary systemic changes in an economical and informed manner. The system described in this work provides users of varying business roles with a single, clear, and concise view of their collaborative, large-scale development projects. This approach provides needed flexibility and functionality, allowing its users to maintain rigorous traceability while minimizing the time and attention needed to maintain valid project records. Further, practitioners are more well-informed regarding change impact and need not rely solely on subject-matter experts' insights and judgments; instead, they rely on artifact provenance to reliably view the past and present of the project and reliably predict future impacts. Combining distributed ledgers and distributed storage creates a scalable, flexible platform for enterprise-grade project management.

Novel Approach in Labeling Data for Classification of Warning Level While Driving
Ana Farhat (Oakland University, USA)

A novel approach for predicting collision warning levels using a classifier that interprets a window of present and past relative positions between the ego vehicle and front object is considered. The premise assumes that the ego vehicle is equipped with a LiDAR, radar or camera that measures the relative distance. A machine learning approach is presented where the feature is the time-to-collision (TTC) which can be determined from Kalman filter estimate of distance, speed and acceleration. The classifier produces classes of warning labels that combines alert levels with watch levels. First part of the classifier called predictor classifier 1, produces the alert levels by evaluating the TTC value of current instance; however, the second part of the classifier called predictor classifier 2, produces the watch labels by applying a novel mathematical algorithm that interprets past values of TTC in a given window. Alert and watch labels are merged together by warning labels generator to produce the final labels for the dataset. This paper presents the formulation and simulation results for the machine learning approach that utilizes neural networks. A future extension of the result will address a deep learning approach where the Kalman filtering & TTC features will be eliminated.

Themed Entertainment in the Age of Coronavirus
Daniel Dunbar and Mo Mansouri (Stevens Institute of Technology, USA)

This paper looks at the effects the current coronavirus pandemic has had on the themed entertainment industry - specifically on Disney Parks and Resorts. It utilizes tools from the Systems Thinking field, including stakeholder analysis, shaping force analysis, a conceptagon triple, causal loop diagrams, and systemigrams to provide insights into the problem space facing Disney theme parks. This analysis reveals aspects of the problem that need to be considered when evaluating potential solutions to interim and long-term challenges presented. It points out the natural boost that the pandemic gave to Disney's streaming service, Disney+, and it explores ways to mimic that phenomenon to provide increase opportunities for the company. It highlights the importance of group experience to theme parks and the prominent role that destination plays in the current makeup of themed entertainment experience. It concludes that design efforts are best aimed at exploring solution spaces that place emphasis on multi-generational experiences that allow connection to the Disney brand without requiring significant extra-party interaction. Augmented Reality is one technology that shows promise for addressing social distancing concerns while fostering group experiences. Design work can and should be both interested in destination experiences and experiences that can be implemented in non-traditional locations.

Design Strategies for Integrating Artificial Intelligence into Systems Engineering Environment
Leandro Batista (Institute Polytechnique de Paris, France); Bruno Monsuez (ENSTA ParisTech, France)

The use of artificial intelligence capabilities in the development of airborne safety-critical systems has been troublesome to the aerospace industry. This technology inserts new sources of non-determinism on process execution, increasing difficulty to ensure safety requirements. In this work we evaluate which artificial intelligence capabilities could be employed to improve systems engineering methodology. From this analysis, we present design strategies to support tool qualification process. The design strategies are a sound basis to allow the application of artificial intelligence into the tools employed during the whole airborne systems lifecycle.

In this paper we investigate the current artificial intelligence capabilities. They are pervasive in a very wide range of applications. The artificial intelligence capabilities can radically improve the systems engineering landscape. We also investigate the tool qualification requirements and guidelines using the DO-178C and DO-330 as reference. These guidelines provide clear guidance for tool qualification.

We also derive operational needs for a large-scale platform. We discuss in detail the need for running applications with different TQL concurrently. We also discuss the need to support applications with independent lifecycle for ensuring agility and low platform qualification cost. Last, we propose a modular design capable of unleashing the strength of artificial intelligence applications.

(UN)ETHICAL SOFTWARE ENGINEERING: A critical review about Software Engineering in face of Security Requirements in the IoT/ IoE Society

Fabiana Flores (Universidade Federal de Pernambuco (UFPE), Brazil); Silvio Meira (Universidade Federal de Pernambuco, Brazil)

Due to the advent of the Internet, software is literally everywhere. This omnipresence of software may impact people's lives in such a way that Software Engineering has reached a level of importance without precedence. Although important, it seems, as a result from real world data analysis, that some practices in Software Engineering may reveal an unethical face that unfolds when considered the disregard of a special kind of non-functional requirements (Security Requirements) and the approach of conditioning software use to the acceptance of abusive documents in which all developers' responsibility for hazards and failures related to software are excluded. The focus of this paper, as a result of an exploratory inquiry based on multiple data gathering (pentesting, observation of software development teams, interviews, survey and documental analysis), is discussing the present relevance of Security Requirements at contemporary societies, as well as the questionable practices of not considering it in software requirements elicitation/ prioritization and the simultaneous conditioning of software use to the acceptance of disregard responsibility clauses in End-User License Agreements and Terms of Services. Results suggest that: a) software insecurity is everywhere, affecting all of the layers of systems and software of several niches; b) insecurity is evident from the great amount of security vulnerabilities found out in software; c) multiple factors contribute to insecurity in software (insufficient developers' knowledge about Security, neglection of security requirements, and omissions in undergraduate courses curricula, e.g.); d) not considering security requirements in nowadays society is unethical; e) it is not appropriate the attitude of part of the Software Industry, that neglects security requirements and, at the same time, tries to hide itself behind EULAs and ToSs filled with responsibility and liability limitation/ exclusion clauses; f) liability and responsibility exclusion/ limitation clauses, as abusive and unethical conditions, shall be suppressed from EULAs and ToSs; g) Software Industry and developers in general shall recognize they are not behaving well and begin doing the right thing from scratch (taking real care for quality and Security Requirements); h) it is time for a change in Software Industry and this change is urgent because inertia, in this case, may favor professional licensing and external regulation initiatives, measures that, obviously, may not be interesting to all the actors involved in software production; i) it is the time for Ethical Software Engineering.

Multi-Agent Based Distributed Dynamic State Estimation Algorithm for Smart Grid Integrating Intermittent Electric Vehicles

Md Masud Rana and Ahmed Abdelhadi (University of Houston, USA)

Large number of physical systems such as electric vehicles and energy storage elements are connected to the main grid. Monitoring and regulating of this interconnected cyber-physical power system state within a short period of time is a challenging task, and it can perform by the process of grid state estimation. First time in the literature, this paper proposes a multi-agent based optimal distributed dynamic state estimation algorithm for smart grid incorporating intermittent electric vehicles and turbines. After mathematically representation of large-scale grid systems into a compact state-space framework, the smart sensors are installed to get real-time measurements which are manipulated by environmental noise. Using mean squared error principle, an innovative distributed smart grid state estimation process is developed and verified. Each agent learns and runs an innovation and consensus type distributed scheme based on local measurements, previous and neighbouring estimated grid states. In this way, each local agent estimated grid state converges to the global consensus estimation over time. The proposed algorithm can effectively reconstruct the original grid states as it executes optimal designed gains. This method has great potential in future real-time applications since it is useful to transmit local information of subsystems to the entire grid in a fully distributed way.

Semantic Mapping from SysML to FRP
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The emerging Digital Engineering demands digital representation of the system of interest and sharing model and data across the boundaries of organizations and the boundaries of the engineering lifecycle. Towards this direction, it is critical to develop systems modeling languages and tools that accommodate Digital Engineering. This paper presents our research on semantic mapping from System Modeling Language (SysML) to Functional Reactive Programming (FRP) with the goal of developing computing mechanisms with functional reactive programming to support executable and verifiable SysML model specification.

Wireless and autonomous safety-critical system utilizing feedback
Thomas Li and Akramul Azim (Ontario Tech University, Canada)

Nowadays, safety-critical systems are becoming more prominent with the increase in reliance on technology in households. With this dependency, reliability and reaction time needs to be improved on to maintain a high standard of service. However, current designs are stagnant and only implementing rote and obsolete open-loop designs as a means of easy manufacturing and for simplicity in design but does not fully provide safety to its users since open-loop designs rely on the user's interaction to initiate the safety process or mitigation. This is too variable and unreliable and delays the process which the user will incur more damages in the end degrading the effectiveness of a safety-critical system. This study aims to addresses these issues by designing a system that implements a closed-loop feedback using values collected from sensors to survey the condition of the surroundings and respond accordingly with different fog computing methodologies and utilizing a feedback loop. This alternative closed-loop implementation will be 40% more reliable than the open-loop version, 71% reduced latency, and have a faster overall response time compared to commercial systems based on the experimental results. All designs, workflows, and ideas discussed in this paper will be implemented all in an Arduino Environment.

Machine Learning with System/Software Engineering in Selection and Integration of Intelligent Algorithms
Jasser Alharbi and Siddhartha Bhattacharyya (Florida Institute of Technology, USA)

Machine learning has become an essential component in the design of intelligent systems across several disciplines. This widespread use of machine learning has led to the importance of evaluating how Systems/Software Engineering approaches go hand in hand with Machine Learning to reliably integrate intelligence in software systems. In this research effort, our motivation is to develop a systematic approach also termed as Machine Learning Engineering for the selection and integration of machine learning algorithms in systems. The proposed approach discusses combining a structured approach for designing and developing system/software with an experimental analysis that data scientists perform on machine learning algorithms. This experimental analysis is essential as some of the characteristics exhibited by intelligent algorithms cannot be predicted or guaranteed compared to systems without intelligent algorithms.

In this paper, we elaborate on our system/software engineering guided disciplined approach by comparing two machine learning algorithms that focus on the recognition of h andwritten digits. The algorithms we compare are the Logistic Regression and Neural Network algorithms. After the analysis, we identify the contracts that should be associated with intelligent components to better predict the behavior of the system as a result of the selection of one of the components to be a machine learning algorithm. Finally, we indicate how the results can be used by Systems/Software Engineers in integrating intelligent algorithms.

Systems Engineering Education & Theory

Systems Engineering Defined
Vegard Haugerud and Mo Mansouri (University of South-Eastern Norway, Norway)

Systems engineering is widely believed to be both critical and beneficial in dealing with complex problems, from its origin until today. Despite this, however, what the term "systems engineering" represents has been the cause of discussions and confusion for a long time. This paper briefly describes the history of systems engineering and its applications, before looking at the problems associated with defining systems engineering and problems associated with already established definitions of the term. This is achieved by reviewing systems engineering definitions found through a collection of a variety of systems engineering literature, including definitions defined by systems engineering standards, the International Council on Systems Engineering (INCOSE), and the Systems Engineering Body of Knowledge (SEBoK). These definitions are reviewed from a systems thinking perspective while applying systems thinking tools and methods.

This paper gathers a collection of key components distilled from the different definitions and their respective literature. The key components are then being considered both individually and holistically before they are integrated to form a new definition of systems engineering, presented at the end of the paper. The propose of the new definition together with a corresponding systemigram is to eliminate some of the confusion associated with systems engineering.

Exploration of the Teaching Method of the Course "Circuit Analysis and Analog Circuits"
Hua Fan (University of Electronic Science and Technology of China, China)

The "Circuit Analysis and Analog Circuits" course for undergraduates is usually difficult to obtain a better teaching effect due to its difficulty, wide range of knowledge, and strong practicality. This has brought certain difficulties for students to master this course. In the traditional teaching method of this course, the theory teaching is usually carried out first, then the simulation is completed through homework, finally carries out the verification experiment of the circuit function module in another experiment course.

However, such teaching methods are usually not effective enough. With such a tight schedule, it is not only difficult to complete the teaching of engineering skills, even the general teaching content is difficult to complete well. If we can put theoretical teaching, simulation, and physical verification closer together, it will enhance teaching in engineering practice, improve learning efficiency.

For analog circuits, the instruments are usually large and heavy, which is an important reason why it is difficult to carry out physical teaching in the classroom in the past. But for some simple basic circuits, the performance of these instruments is usually excessive. To make teaching in the classroom more convenient and show the circuit effect more clearly, we have made some signal sources and power modules. Since a large number of self-made measuring instrument projects have appeared in the open-source community in recent years, some low-cost, portable and open-source instruments have been produced, such as voltmeters, oscilloscopes, vector network analyzers (VNA), etc. The performance of these instruments is sufficient to complete the measurement of these simple circuits with low working frequency, bringing an intuitive understanding of the circuit.

For example, a popular vector network analyzer called NanoVNA can be used in experiments to observe the frequency response of RLC passive filters. NanoVNA is a portable vector network analyzer with a smaller size than common mobile phones. When demonstrating the usage of RLC filters, if the oscilloscope is used to observe the changes in the waveform, it needs to have a high sampling rate. Besides, the difference between input and output signals' waveforms are often not obvious. NanoVNA can measure the characteristics of the system's input and output signal amplitude changing with frequency and display it on the built-in display.

This paper shows the use of NanoVNA to measure the frequency response of a passive low-pass filter composed of RLC. The blue line on the screen is the S21 parameter, which decreases as the frequency increases. By changing the resistance of the resistor that constitutes the filter, the cutoff frequency changes with the change of the resistance in real-time.

Besides, a portable oscilloscope is used to measure some low-frequency waveforms. This oscilloscope is not only small enough but also comes with a 1kHz square wave signal source. When demonstrating the charging and discharging of the RC circuit, this paper shows the effect observed after connecting the signal source output to a capacitor, which is connected to the ground, and the input probe at the same time. By comparing the effect before and after connecting the capacitor, it is easier to understand the role of the capacitor in the circuit.

In a conclusion, it is often difficult for universities to effectively teach in engineering practice in current courses related to the analog circuit. It brings obstacles to students in scientific research, and make them difficult to meet the requirements of enterprises after graduation. Adding teaching content on simulation and engineering practice effectively in limited teaching time is a way to solve this problem. Through a series of cases of classroom teaching and tasks after class, the attempts to improve students' engineering practice ability have been proved effective.

Strengthening the Practical Capacity of Students: an Educational Case Study about Teaching Feedback in Electronics Circuit
Hua Fan (University of Electronic Science and Technology of China, China)

With the advent of information age, electronic products have gradually entered people's lives. The sending, receiving and processing of information can not be separated from electronic products. The foundation of the development of electronic industry is the basic knowledge course of that major.

Learning the analog circuit foundation well can lay a solid professional foundation for every student. As well known, there are some difficult concepts in analog circuit. Students need to learn to understand it by using scientific analogical thinking method. It can not only deepen their understanding of knowledge points, but also urge students to apply book theory to real life and learn knowledge "alive". The characteristic of the analogy method is to defer first and compare later. The fundamental basis of analogy is "comparison". "Comparison" must compare the common points as well as the differences. The common ground between the problems is the prerequisite for the analogy method to be used. The problems without the common ground cannot be reasoned by analogy. The analogy method is not only an effective method for exploring problem-solving ideas, guessing the answer or conclusion of the problem, but also a method of reasoning from special to special. Analogy is the basis of all knowledge and understanding.

As a method of logical reasoning, The application of analogy method in curriculum teaching is of great significance. Analogical thinking and analogical teaching play an important role in college curriculum and analogical thinking also runs through the whole process of education and teaching. It has the basic functions of guessing and conjecturing new conclusions, exploring and providing ideas for solving problems and establishing the connection between new and old knowledge. For example, as for the capacitor, the voltage at both ends of the capacitor can not change, because voltage is the process of charge accumulation and the accumulation of charge takes time, so the voltage can not change. Through analogy, it can be compared to a process of dam water storage. Whether it is heavy rain or artificial water storage, it takes a certain time for the water level of the dam to rise. The capacitance characteristics and the dam are cleverly linked to make learning the process of learning becomes more interesting, which enhances students interest in learning, reduces the difficulty of knowledge points and enhances students confidence in learning. Facing the requirements of advancing the strategy of training elite talents, optimizing the talent training system and building first-class undergraduate education,

the training of elite talents not only emphasizes problem-solvingł “how to do it?”, but also emphasizes thinking about problemsł “what to do?” to help students view and solve problems from a broader perspective, interdisciplinary and systematic thinking. In the teaching process of “electronic circuits”, we have clearly realized that with the rapid development of electronic circuit technology, electronic equipment has become increasingly integrated, electronic design automation (EDA) and the rapid development of various circuit simulation software have greatly simplified the complex circuit analysis and calculations. Because the world is analog, the signals in nature are analog signals, and analog circuits are inseparable from real life. Therefore, we have proposed a comparative teaching strategy of electronic circuit technology with “analogous thinking method”. The so-called analogy thinking refers to the logical reasoning method that transfers the knowledge of one special thing to another special thing based on the similarity or similarity in some aspects between two or two kinds of things. When two types of things are the same or similar in one or some aspects, analogy thinking can be used. In this paper, application of analogy as well as inspiring methodology in teaching feedback amplifier circuit have been given as a case study.

Systems Integration and Verification

The roles of modeling and simulation in assessing spacecraft Integration Readiness Levels
Gabriel Torres de Jesus and Milton Chagas Júnior (Instituto Nacional de Pesquisas Espaciais (INPE), Brazil)

Introducing new technologies in Complex Products and Systems (CoPS) requires in-depth knowledge of technology and the system integration process. Technology Readiness Assessment (TRA) is a systematic evidence-based process that assesses technology maturity based on Technology Readiness Levels (TRL). System Readiness Assessment (SRA) is the process of conducting integrated assessments of a developing system to assess technology maturation and provide a systemic understanding of the development life-cycle. The Integration Readiness Levels (IRL) scale complements TRL in representing integration between technological elements in a system, and both scales are used in SRA to calculate system readiness metric. SRA is expected to be an emerging systems engineering best practice and has evolved over the last decade. However, SRA does not explicitly guide whether simulation could comply with IRL dedicated to interface verification and validation (V&V).

Modeling and simulation (M&S) play many roles in systems engineering. Digital and M&S technologies advancement, as Model-Based System Engineering (MBSE) and digital twins, may contribute to reducing space missions´ costs and schedule, along with trends in systems and technology reuse.

This research identified the possible roles of modeling and simulation in assessing spacecraft Integration Readiness Levels. Results showed M&S possible roles for each IRL, whether the roles are essential or support to achieve a specific IRL. Also, a link between the system life cycle and these results contributes to the SRA research stream. A case study with the China-Brazil Earth Resources Satellite (CBERS) program was used to validate part of the proposed theory, in line with other cases extracted from the literature. This paper contributes to the SRA research stream with these theoretical and practical results, suggesting future studies that could improve SRA practice, and consequently support the decision making on technology introduction in CoPS.

Transportation Systems

Flying Robots for Safe and Efficient Parcel Delivery Within the COVID-19 Pandemic
Manuel Patchou, Benjamin Sliwa and Christian Wietfeld (TU Dortmund University, Germany)

The integration of small-scale Unmanned Aerial Vehicles (UAVs) into Intelligent Transportation Systems (ITSs) will empower novel smart-city applications and services. After the unforeseen outbreak of the COVID-19 pandemic, the public demand for delivery services has multiplied. Mobile robotic systems inherently offer the potential for minimizing the amount of direct human-to-human interactions with the parcel delivery process. The proposed system-of-systems consists of various complex aspects such as assigning and distributing delivery jobs, establishing and maintaining reliable communication links between the vehicles, as well as path planning and mobility control. In this paper, we apply a system-level perspective for identifying key challenges and promising solution approaches for modeling, analysis, and optimization of UAV-aided parcel delivery. We present a system-of-systems model for UAV-assisted parcel delivery to cope with higher capacity requirements induced by the COVID-19. To demonstrate the benefits of hybrid vehicular delivery, we present a case study focusing on the prioritization of time-critical deliveries such as medical goods. The results further confirm that the capacity of traditional delivery fleets can be upgraded with drone usage. Furthermore, we observe that the delay incurred by prioritizing time-critical deliveries can be compensated with drone deployment. Finally, centralized and decentralized communication approaches for data transmission inside hybrid delivery fleets are compared.

Application of Statistical Machine Learning Algorithms for Classification of Bridge Deformation Data Sets
Juan Avendano (150 W University Blvd & Florida Institute of Technology, USA); Luis Daniel Otero and Carlos Otero (Florida Institute of Technology, USA)

This paper presents the application of statistical machine learning (ML) algorithms to classify deformation datasets of bridge structures. A model of a steel bridge was constructed to measure structural deflections when subjecting the bridge to various loading scenarios. Similar to other studies presented in the academic literature regarding bridge health monitoring, contactless sensors as well as sensors embedded in the bridge were used for data collection. A contactless OptiTrack system was used to collect deformation data at the sensor locations with an accuracy of 0.2mm. In order to identify the probability of bridge deformations, 15 types of statistical models were developed. The Python programming language was used for coding and analyses were performed in a Google Collaboratory Notebook. Development and training of the models were done using Pycaret, which is a Python-based framework that supports a variety of ML tools. Performance of each ML technique was evaluated for accuracy. Although various statistical models and ML algorithms have been employed in studies related to health monitoring of bridge structures, there is still a need to continue research efforts in this area to provide further evidence of the potential gains to the transportation field from the application of data science approaches. The paper concludes with areas for future research.

Optimization of Sensor Placement in a Bridge Structural Health Monitoring System
Juan Avendano (150 W University Blvd & Florida Institute of Technology, USA); Luis Daniel Otero and Carlos Otero (Florida Institute of Technology, USA)

This paper presents an optimal sensor placement technique designed to be implemented on structural health monitoring systems. A steel bridge was modeled in ANSYS environment and four load values were applied at pre-identified locations to generate data. Each experiment yielded an array of data that contains the location, as well as corresponding deformation and safety factors. Measurements were taken at 1,000,000 positions on the model bridge and a library of a similar number of failure modes was created for each experiment. Each data library was processed as a multi-dimensional matrix by applying an average filtering algorithm. Local extrema were identified in terms of the corresponding deformation and safety factors by removing repeated values at nearby locations. The results provided a list of 100 locations with maximum deformation or minimum safety factors, containing the optimized positions on the model bridge for placement of sensors. The final developed system that includes this placement algorithm is capable of simulating multiple load conditions on structures, identifying possible failure points, and detecting and predicting failure scenarios. Both hardware and software implementations of a model of a bridge were performed as a pilot project to validate the proposed system. The paper concludes with future areas of research.

A CADDEX tool for CAD and CAE integration

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In recent years, the CAD-simulation integration becomes more than important in the design of complex mechanical products. In CAD environment, the simulation incorporates not only the FEM simulation, but also the simulation of assembly and disassembly plans, tolerancing, etc. The mock-up of mechatronic products made by CAD systems must respond to the requirements given by the system engineer. This loop, when automated, ensures the interoperability between different systems of an industrial product. However, in the reality, there is a lack of continuity between the CAD designer and the system engineer. Some CAD data are needed to be transferred to Computer Aided Engineering applications (CAE) such as: part's data (mass, volume, inertia matrix, center of mass coordinates…) and the assembly data (assembly constraint, assembly matrices, dynamic collision, etc.). In this paper, a FreeCAD Workbench application is developed and implemented as an open-source tool. The main objective is to question the CAD system in order to extract relevant data and export them under a standard format. The SysML graphic formalism is used to develop the proposed tool, named CADDEX©. Using the implemented tool, the collected data parts are exported as an XML format which is used by the system engineering (SE). An illustrative example is used to highlight the advantages and limitations of the proposed tool.

Context-Aware Model-Based Requirements Engineering Facilitates Capability Evolution

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Evolutionary system development and capability deployment are becoming common even in aerospace and defense. As systems evolve, a significant understanding of the context of each new requirement is necessary, in order to maximize re-use, minimize modifications, and prevent inconsistencies across the architecture. At the same time, the pressure to transition into a model-based system architecture grows. At present, requirement specifications cannot clearly separate the baseline from the necessary delta. We propose Context-Aware Model-Based Requirements Engineering (CAMBRE) as a requirement specification method in which the context of a requirement is modularly composed with its prospect, allowing for specifying the requirement text in a context-aware manner. The context informs the prospect and grounds it in the given architecture. The prospect specifies what the requirement owner needs, requires, or expects the system to be or do. We distill those parts of a requirement that are designated for development from those that constitute the background. This approach is acute for complex, evolving, interdependent, or adaptive systems, in which system properties mostly extend or enhance the existing architecture. We implement CAMBRE with Object-Process Methodology (OPM), and demonstrate our approach on the evolutionary extension of a missile defense system with drone interception capabilities to support border protection efforts.

Differential Privacy for Fair Deep Learning Models
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Increasingly, we rely on deep learning to make decisions. Yet, these models may take unfair decisions due to bias in the training data-sets. Most of the time, this bias is discrimination due to sensitive attributes such as gender, race, or ethnicity. In fact, discrimination and inequities are a daily reality that continues to exist in many fields, e.g. hiring processes, tenures, and workplaces. Therefore, exiting data-sets may be biased which results in getting unfair learning models.

In this paper, we empirically prove that learning models trained on biased data-sets will produce unfair and discriminating models. To handle this problem, we propose a pre-processing approach that takes advantage of differential privacy properties to mitigate bias in sensitive attributes of data-sets. More precisely, in the learning process, we introduce the randomized response mechanism to mitigate the inequity and avoid discrimination from the training data-set. We evaluate our approach in a hiring process using a synthetic data-set of resumes of candidates.

Simulation results show that our approach mitigates bias and takes more fair decisions compared to the TensorFlow differential privacy library or a learning model without our pre-processing approach. This is owing to the fact that the TensorFlow library applies differential privacy to all attributes, Whilst in our approach we only apply the differential privacy mechanism to sensitive attributes that are the source of the discrimination.

Estimating Helicopter Gross Weight Using HUMS Data
Eric R Bechhoefer (40 Ridge Rd & GPMS Inc, USA); Thomas Wells (Purdue Univserity, USA)

Weight and balance are part of every pilot's preflight. Gross weight (GW) and center-of-balance impacts the static and dynamics of flight. However, from a condition monitoring perspective, understanding the GW could be used to determine the accumulated damage to structural component. This, in turn, allows for the calculation of components remaining useful life and improved retirement time of structural components. As life limits for a critical component are based on the worst-case assumption of usage, an actual estimate of GW allows for a more accurate assessment of loads, thus providing a more precise usage spectrum. This then provides a path toward extending the time between overhaul or extending the maintenance interval. This paper solves for GW using Health and Usage Monitoring System (HUMS) parameter data to solve an inverse performance problem.

For future vertical lift aircraft, designing in the calculation of weight could be used to improve the aircraft's performance. Weight and balance affect the static and dynamic characteristics of the helicopter. The known weight would be an enabling technology for advanced automatic flight control systems and supporting condition-based maintenance. The known weight could also be used to validate the usage spectrum of the aircraft. An actual usage spectrum would use the existing calculations of time for life-limited components, based on the real spectrum of usage, to allow for a credit or extension.

Multi Base Stations to Multi Mobile Units: Green Communication Systems via A Wavefront Multiplexing Technique

Hen-Geul Yeh (California State University Long Beach, USA)

A green communication scheme using an orthogonal wavefront (WF) multiplexing scheme spatially combined with orthogonal frequency-division multiplexing (OFDM) techniques is proposed. It forms a spatial WF OFDM transceiver. The WF multiplexing technique serves as the preprocessing and postprocessing method of the WF OFDM transceiver. With coordinated multiple point forward transmission, this spatial WF OFDM system establishes a communication network. It can be applied to multiple base stations (BSs) with down links to a single or multiple mobile units (MUs). Although signals received are non-coherently due to different distances between BSs and MUs, they can be compensated and coherently combined via adaptive equalizers at MUs. This is achieved by using pilot signals with an optimization method at the receiver of MUs. Simulation results demonstrate that the WF OFDM scheme obtains the same bit error rate (BER) as predicted by theory in an additive white Gaussian noise (AWGN) channel. Moreover, the required effective equivalent isotropically radiated power (EIRP) from BSs to the MUs is significantly reduced due to multiple non-coherent transmission. Accordingly, the interference to adjacent frequency bands' signals will be low. This green communication network is achieved via the combination of WF multiplexing, OFDM, and optimization at the receiver together. More investigations are needed to show that this WF OFDM transceiver can be applied to frequency selective mobile fading channels.

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