# Parallel session 1.1:
# 3D Modelling and structures

## Session Chair: José Ríos, Universidad Politécnica de Madrid, Spain

1:30pm-
1:50pm

**Augmented Reality for Operator Training on Industrial Workplaces – Comparing the Microsoft HoloLens vs. Small and Big Screen Tactile Devices**

**Andreas Pusch, Frédéric Noël**
Univ. Grenoble Alpes, CNRS, Grenoble INP, France

The digital revolution towards the industry standard 4.0 offers many ways to improve established methods and processes. In this paper, we report on the lessons learned about the pros and cons of Augmented-Reality-based operator training using the Microsoft HoloLens as compared to small and big screen tactile devices. Together with our industrial partner, we have chosen an encapsulation assembly task as use case. We have enriched the original training material with digital twins of the workplace, animations, videos, and contemporary forms of interaction, all of which made available in an optimised fashion on three different support technologies. Feedback from our testers, and those in charge of designing training courses, is suggesting that notably the HoloLens version of our prototype has the potential not only to replace current training methods, but to go beyond them up to the point where even novices can pass the training autonomously. It thus seems promising to integrate Augmented Reality into training programmes and so to complete the digital chain within the industry life management.

1:50pm-
2:10pm

**Computer vision with cognitive learning to improve the decision-making during the sales process in physical stores**

**Vinicius da Silva Ramalho, Anderson Luis Szejka, Marcelo Rudek, Osiris Canciglieri Junior**
Industrial and Systems Engineering Graduate Program, Pontifical Catholic University of Parana, Curitiba, Brazil

In a world where the information is obtained faster than ever seem, new methods to analyze and extract information and knowledge from this high volume of data are being developed. This is more notorious in a virtual ambient where the data is generated in a manner that is faster and easier to analyze than in the real world. This is very evident in the retail field, where virtual stores have easy access to all the advertisement a user visited and simple to obtain user profile, on the other hand physical stores are limited to basically create a register in a database when there is a purchase. This paper proposes to develop a computational model that will automatically analyze the people flow in a physical store, to inform the retailer the amount of people and their gender to support the sales decision-making process in physical stores. To this end, computational vision methods and cognitive learning algorithms were studied and evaluated, and the most suitable methods were structured in a theoretical conception model and implemented in a computational tool. This solution was tested in a real scenario operating in a local mode and remote mode in real time. Two scenarios were evaluated: static ambient light and dynamic light. Three tests were conducted: YOLOv2 against Background Subtraction; Background Subtraction performance in both scenarios; gender classification using full body features. Even though the results were not as positive as needed for commercial use, the tools demonstrated potential for application in this context.

2:10pm-
2:30pm

**REVIEW OF CAD VISUALIZATION STANDARDS IN PLM**

**Stephane NZETCHOU, Alexandre DURUPT, Sébastien REMY, Benoit EYNARD**
Université de Technologie de Compiègne, France; Université de Technologie de Troyes, France

The rise of new technologies has led to a growth in the number of 3D data. More 3D data are voluminous, greater the number of interrelationships between the data. These data can come from various sources, hence their heterogeneity and complexity. The level of data access is often a function of the user's expertise since the 3D data are complexes and registered to different file formats. A 3D data file format is used for storing information about 3D models. Each sector adopts his own 3D file format for different reasons. In this article, we are going to learn about 3D file formats and survey the functionality differences between some popular file formats, able to ease the integration of data, by analyzing on 3D viewing technology, some drawings made by two different CAD systems.

2:30pm-
2:50pm

**Octree based Voxel Model for representation of spatial conflicts across multiple design domains**

**Arun Kumar Singh, B Gurumoorthy, Latha Christie**
Indian Institute of Science, India; Microwave Tube Research and Development Centre, Bangalore, India

This paper discusses use of octree based voxel model for representation of spatial conflicts across multiple design domains. A framework has been developed to create Octree based Voxel Model linked with intended empty spaces in product, which are associated with design requirements, product lifecycle states and connected design domains. Knowledge in System Modelling Language (SysML), is used to select criteria for building octree based voxel model. A case study of Coupled cavity travelling wave tube (CCTWT) Slow Wave structure (SWS) design has been taken to showcase the code capabilities. Octree voxels inside CAD platform show and represent spatial conflicts, detected by associativity modelling of Empty space blocks inside CAD along with the Product knowledge in SysML model.

2:50pm-
3:10pm

**A review, focused on data transfer standards, of the uncertainty representation in the digital twin context**

**José Ríos, Georg Staudter, Moritz Weber, Reiner Anderl**
Universidad Politécnica de Madrid, Spain; TU Darmstadt, Germany

In the context of the digital twin, it is recognized the relevance and challenges of the uncertainty quantification. Data acquired from the physical domain are incorporated into a cyber-space to assist in predictive and decision-making processes. The acquisition of data in the physical domain involves the measurement of physical magnitudes. The digital as-built or as-manufactured model derives from measured or scanned data of a physical product. Thus, it is relevant to know how much true the data are. The uncertainty of a measured magnitude is a significant indicator of the data truthfulness. This work shows how the uncertainty is being modeled in standards related to product data representation and in an engineering data fusion context. As an example of a data fusion context, the ongoing uncertainty modeling work in the Collaborative Research Center (SFB 805) at TU Darmstadt is presented.

# Parallel session 1.2: PLM and Conceptual Design

## Session Chair: José Ríos, Universidad Politécnica de Madrid, Spain
## Lars Hagge, DESY, Germany

1:30pm-1:50pm **Graph based tools for ECM search result analysis to support the ideation step**

**Houcine Dammak, Abdellatif Dkhil, Mickael Gardoni**
École de Technologie Supérieure, Montréal, Canada; Institut National des Sciences Appliquées, Strasbourg, France

ECM is defined as the technologies, tools, and methods used to capture, manage, store, preserve, and deliver content. Using ECM in the ideation step of the innovation process may enhance the creativity of users to create new knowledge. ECM users will have access to valuable information that is structured and easily accessible. Some researchers proved that access to large databases of information can overwhelm users, in their innovation process, and tend them to return to known solutions which will decrease the creativity [1].To avoid this situation, instead of presenting the results of the research to the participants as a content list with related metadata, we will propose a graphical representation with a relational analysis between these contents. In this paper, we propose to use the graph theory to visualize and analyze the result of the ECM application.

1:50pm-2:10pm **A Property Graph Data Model for a Context-Aware Design Assistant**

**Romain Pinquié, Philippe Véron, Frédéric Segonds, Thomas Zynda**
Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP, Grenoble, France; LISPEN, Arts et Métiers ParisTech, Aix-en-Provence, France; LCPI, Arts et Métiers ParisTech, Paris, France; Capgemini, Toulouse, France

[Context] The design of a product requires to satisfy a large number of design rules so as to avoid design errors. [Problem] Although there are numerous technological alternatives for managing knowledge, design departments continue to store design rules in nearly unusable documents. Indeed, existing propositions based on basic information retrieval techniques applied to unstructured engineering documents do not provide good results. Conversely, the development and management of structured ontologies are too laborious. [Proposition] We propose a property graph data model that paves the way to a context-aware design assistant. The property graph data model is a graph-oriented data structure that enables us to formally define a design context as a consolidated set of five sub-contexts: social, semantic, engineering, operational IT, and traceability. [Future work] Connected to or embedded in a Computer Aided Design (CAD) environment, our context-aware design assistant will extend traditional CAD capabilities as it could, for instance, ease: 1) the retrieval of rules according to a particular design context, 2) the recommendation of design rules while a design activity is being performed, 3) the verification of design solutions, 4) the automation of design routines, etc.

2:10pm-2:30pm **A Novel Approach to Product Lifecycle Management and Engineering Using Behavioural Models for the Conceptual Design Phase**

**Stephen Peters, Clement Fortin, Grant McSorley**
University of Prince Edward Island, Canada; Skoltech, Russian Federation

This work builds upon a previous proposal for the use of the extended SAP-PhIRE model of causality as a foundation for a PLM system, and more spe-cifically the management of design data at the conceptual design phase. Dur-ing the conceptual design phase, the product definition is in a state of flux as multiple iterations and options are considered until a suitable baseline design is developed. The role of PLM systems is to manage the people, processes and products involved in developing and sustaining a product in order to in-crease stakeholder satisfaction and product quality while reducing lifecycle costs. At the conceptual design stage, a balance must be struck between the freedom to iterate and the need to control the design process and capture rel-evant data.

Currently, PLM systems are not well suited for the support of the concep-tual design stage due to their reliance on the product structure, as the una-voidable, significant design changes to the physical configuration in the early design stages make it difficult to maintain a coherent product definition. This paper presents a case study of the product data created during the conceptual design phase of the SpudNik-1 CubeSat. The results demonstrate the ability of the model to represent a variety of design data representing different sub-systems at several levels of maturity. This could prove to be more consistent and easier to use for conceptual design and is one part of a larger goal of re-designing PLM systems for the support of the extended product lifecycle.

2:30pm-2:50pm **Toward a Hybrid Agile Product Development Process**

**Nicola Garzaniti, Clément Fortin, Alessandro Golkar**
Skoltech, Russia

Both startups and traditional space industry are exploring new business opportunities and new engineering approaches in what is becoming known now as New Space.

Organizations started accelerating project schedules and challenging the V-model typically used in space product development. The need of a faster and more adaptive response to changing customer needs within an improved development productivity made Agile process a potential key enabler of New Space sector.

On the other hand, space system projects are typically executed in multi-party consortia. Each organization in a consortium adopts its own product development process and interprets "New Space" differently. For this reason, the implementation of Agile is not seamless as it requires coordination with traditional systems engineering approaches. This setup is what we refer to as "hybrid Agile product lifecycle management".

This paper provides a first definition of the architecture of hybrid product lifecycle management targeted toward systems development and lifecycle management of hardware projects developed by multi-party consortia. We consider this discussion in the context of the development of spaceflight hardware in the New Space industry. We identify the main challenges in adopting such a methodology in developing hardware systems. This work identifies opportunities of future work for defining coordination approaches in hybrid product development settings, and improved organization structures of hardware projects in hybrid development contexts

2:50pm-3:10pm **A data preparation and migration framework for implementing modular product structures in PLM**

**Muni Prasad Giddaluru, James Gao**

Cummins Power Susyems, United Kingdom; University of Greenwich, United Kingdom This paper reports the research on the complex process of implementing modular product structures in a Product Lifecycle Management (PLM) system. There are many challenges to system implementation. One main challenge is organising or mapping existing product data and migrating it to the new PLM system. Companies often use a PLM tool for management of CAD files, documents and drawings, but they do not take advantage of the full potential of the PLM system to support the development activities of modular products. Product data management tools are used mainly for product CAD data management and PLM systems support by automating and managing some of the operational complexity of modular product design. The aim of this research is to propose a data model that can be used for implementing modular product structures in a PLM system and a tool that can formalise the existing data so as to migrate it into the PLM system.

# Parallel session 1.3: IoT and PLM

## Session Chair: Benoit Eynard, UTC, France

1:30pm-
1:50pm

**Towards a digital thread between internet of things and product lifecycle management: experimental work for prototype implementation**

**Piers Barrios, Benoit Eynard, Christophe Danjou**
Université de technologie de Compiègne, France; Gfi Informatique, France; Polytechnique Montréal, Canada

With the growing number of internet of things (IoT) and their miniaturisa-tion, the technical possibilities associated with data collection are multi-plied. In the future, it will be possible to install a sensor anywhere for a small cost. On the other hand, product lifecycle management (PLM) is a growing societal concern and products will need to be designed in such a way as to minimize their impact, while allowing businesses to have a viable business model. It will therefore be necessary to integrate data, coming from industrial internet of things (IIoT) into product lifecycle management, for companies to be able to offer product-as-a-service and pay-to-use. This pa-per aims to describe current advances on the integration of industrial inter-net of things in product lifecycle management. It also describes a prototype for a digital thread between IIoT and PLM allowing us to put forward open questions regarding the integration.

1:50pm-
2:10pm

**Digital Twin – Integrating cloud services into communication protocols**

**Thomas Dasbach, Eduardo de Senzi Zancul, Klaus Schützer, Reiner Anderl**
TU Darmstadt, Germany; University of São Paulo, Brazil; Methodist University of Piracicaba, Brazil

The Digital Twin is the following development of ongoing improvements in communicational technologies, decreasing hardware costs and the need for products with decentralized decision-making abilities. In order to improve the qualities of decisions, there is the requirement for an easy, reliable way to transport data between Digital Twins, even if the network connection has a low bandwidth or is even unstable. As a solution, the use of a cloud service as a broker architecture is described. A concept for communication architec-ture is given as well as the required design of a Digital Twin. The proposed concept has been implemented to assess the resulting advantages and limita-tions.

2:10pm-
2:30pm

**Development of a valuation method for IoT-platforms**

**Stefan Kugler, Cordula Auth, Reiner Anderl**
TU Darmstadt, Department of Computer Integrated Design, Germany

A production facility enables the collecting of many different data with existing machinery. One reason for this are modern machines, which are usually equipped with cyber-physical-systems (CPS). CPS are the basis of Industrie 4.0 and ena-ble machines to collect and transfer data by using sensors and a communication interfaces. The IoT-platform can visualize and analyse the data collected. This en-ables production to be optimized by detecting and minimizing weak points. Due to the topicality of this topic, there is a large variety of platform providers on the market. However, the IoT-platforms of the different providers have different strengths and weaknesses. In order to be able to keep track of existing IoT-platform solutions and to be able to better point out advantages and disad-vantages, this paper presents a method that supports the suitability and choice of an IoT-platform solution.

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For this reason, a method will be developed which is based on a matrix in which selected IoT-platform solutions are listed. In addition, criteria for evaluation are detected and an evaluation scheme is integrated. Based on the evaluation the method determines a suitable IoT-platform by taking the customer needs into ac-count. After a brief introduction and portraying the state of the art, the concept of the evaluation matrix follows followed by an outlook and a short summary.

2:30pm-
2:50pm

**Impact of IIoT based technologies on characteristic features and related options of nonownership business models**

**Karan Menon, Hannu Kärkkäinen, Sameer Mittal, Thorsten Wuest**
Tampere University, Finland; West Virginia University, USA

Industrial internet of things (IIoT) has huge potential to impact various businesses from the process and technical point of view. There is a limited understanding of the impact of IIoT on business models in general especially the novel nonownership business models (NOBMs). In this paper we analyze the literature, especially case study literature, to understand the impact of IIoT based technologies and related features on the NOBMs using a morphological box as a framework. We analyze the impact of IIoT on the characteristic features and related options of the morphological box developed by Lay et al. 2009. We understood that IIoT- enabled technologies and facilitated process capabilities impact the above-mentioned characteristic features and related options in a way that this enables the implementation of a larger variety of NOBMs, such as, the pay-per-use, pay-per-output and pay-per-outcome business models, as well as a variety of options related to them. We also realized that there is a need to develop a morphological box for capital intensive manufacturing companies by developing new characteristic features and related options that can take IIoT enabled technologies and facilitated process capabilities into account.

# Parallel session 1.4: Ontologies and semantics

## Session Chair: Alexander Smirnov, SPIIRAS, Russian Federation

3:45pm-4:05pm

### A preliminary method to support the semantic interoperability in Models of Manufacturing (MfM) based on an ontological approach

**Anderson Luis Szejka, Osiris Canciglieri Junior, Fernando Mas**
Pontifical Catholic University of Parana, Brazil; Airbus, Seville, Spain; Universidad de Seville, Seville, Spain

The product design and manufacturing complexity has been increased the last few years. This has challenged the manufacturing industry to rationalise different ways of bringing to the market novel products in a short lead-time with competitive prices while ensuring higher quality levels and customisation. Design and Simulation systems bring to the product developer experts an abstraction required for the design of complex products. However, for complex product manufacturing process has required simultaneously collaborations with multiple groups, exchanging information from multi-perspectives within and across institutional boundaries. Thousands of different information must be exchanged across heterogeneous systems. Semantic interoperability obstacles have been identified in view of the information heterogeneity from multiple perspectives and their relationships across different phases of product manufacturing. In this context, this paper presents a preliminary method for Models for Manufacturing (MfM) to support the semantic interoperability across the manufacturing system based on reference ontologies, application ontologies and semantic rules. The MfM has been modelled in reference ontologies and specialised to perform multiple specific applications according to the product to be manufactured. Semantic rules are used to share, convert or translate information from multiple perspective to infer relation between multiple manufacturing levels. This preliminary method was applied in a case of an aerospace industry. The main research contributions are: (i) the intelligence structuring information in elementary concepts responsible for representing the MfM, modelled in the core ontologies and (ii) the improvement of information exchanging from heterogeneous domain across different phases of manufacturing process based on the semantic rules.

4:05pm-4:25pm

### Building a Multi-Aspect Ontology for Semantic Interoperability in PLM

**Alexander Smirnov, Nikolay Shilov, Vladimir Parfenov**
ITMO University, Russian Federation; SPIIRAS, Russian Federation; ITMO University, Russian Federation

Interoperability support is a key task to enable seamless integration between various information systems. Today, in the era of Internet of Things and cyber-physical systems more and more systems have to collaborate. Product lifecycle management is not an exception. It covers multiple processes related to all stages of the product lifecycle and usually aimed at solving various tasks using different apparatus. As a result, a dilemma arises: on the one hand, there is a need of common information models enabling seamless information exchange, and on the other hand, the existing information models need to be preserved in order not to loose the already achieved efficiency in solving various tasks. In the present re-search, the problem of developing a single ontology for PLM support is investigated taking into account differences between terminologies (multi-aspect ontology) used at various stages of the PLM cycle. In this paper, the process of the multi-aspect PLM ontology building is presented based on the case study of PLM support at the automation equipment producer Festo AG & Co KG.

4:25pm-4:45pm

### Essential Knowledge Management in Product Lifecycle Management implementation

**Daniela Oliveira, Mickael Gardoni, Kimiz Dalkir**
École de Technologie Supérieure, Canada; School of Information Studies, McGill University, Canada

This study outlines the importance of tacit knowledge for engineering organizations, specially engineer-to-order organizations, and its impact in Product Lifecycle Management (PLM) implementations. The use of maturity models as roadmaps and its functions in PLM and knowledge management (KM) are explored. Difficulties of managing knowledge to prepare an organization for PLM implementation, and how PLM maturity models lack the granularity to support KM for PLM implementations are explored. Considerations to make maturity models easier to translate into action are made. To support KM for PLM implementations, KM and PLM initiatives and states are presented in relation to tacit knowledge areas and PLM readiness levels. To create this matrix, a methodology involving content analysis and decomposition followed by categorization according to tacit knowledge areas is applied to a PLM maturity model suitable for engineer-to-order organizations. The matrix intends to help knowledge managers better prepare the organization for a PLM implementation and better support the implementation effort.

4:45pm-5:05pm

### An Approach to Semantic Interoperability for Product Development through Automatic Requirement Extraction and Semantic Reconciliation

**Matheus Beltrame Canciglieri, Athon Francisco Curi Staben de Moura Leite, Anderson Luis Szejka, Osiris Canciglieri Junior**
Industrial and Systems Engineering Graduate Program, Pontifical Catholic University of Parana, Brazil

The strong competitiveness challenges manufacturing industry to rationalize different ways of bringing new products to the market in the shortest time with competitive prices while ensuring higher quality. Industries need to effectively share product requirements, which comes from various sources and are heterogeneous in nature, during the Product Development Process (PDP) to stay competitive. However, problems with misinterpretation of such requirements have been identified during its sharing due to semantic interoperability obstacles related to the process of automatically gathering requirements and their translation and reuse. This research proposes an approach to automatically gather product requirements, extracting its knowledge and translate it for further use and reuse along PDP. The research structure consisted of firstly studying the current issues of the topic, secondly by exploring an approach, to be validated in an experimental case. Current issues point out to gaps related to the process of semantic reconciliation and knowledge extraction perspectives, giving it a multi-dimensional panorama where semantic issues are intertwined among different perspectives. The later solution presents an approach which considers raw information being processed into product features, refining knowledge during PDP and making it reusable in different cycles. The approach brings a new view on practical methods for automatically collect product requirements, extract its knowledge and translate it into product features, based on knowledge extraction methods and by using semantic reconciliation as means for translating product's requirements. Further research will focus on expanding the approach and including more features to increasingly complex cases, to explore the full potential of the approach.

5:05pm-5:25pm

### Communication Protocol Application for enhanced Connectivity of Sensors, Machines and Systems in Additive Manufacturing and Production Networks

**Cordula Auth, Stefan Kugler, Jennifer Greven, Reiner Anderl**
TU Darmstadt, Department of Computer Integrated Design, Germany

The connection between sensors, systems and machines in the production environment enables new concepts to increase quality or flexibility. Integrated sensors can measure machine performance parameters. The measurements serve for monitoring of process stability and quality or for affecting production planning through a new agile routing. To realize the new concepts, data needs to be transmitted from the sensors to a data management system, where the collected data can be analyzed and stored. The communication between sensors, machines and systems is a central aspect and, there-fore, a big challenge. There exist different protocols to enable communication, but choosing the proper protocol for a special use case is difficult. There does not exist a method that supports the choice of the protocol de-pending on the initial situation and the user's preferences. Therefore, the aim of this paper is the development and implementation of a method that supports the selection of a communication protocol in an Industrie 4.0 sur-rounding for enhanced connectivity between sensors, systems and machines in the production depending on the individual initial situation and the per-sonal preferences. After a short motivation and state of the art, two use cases are described and the development of the concept is explained. The following implementation shows the realization of the concept and enables the use of the concept on the two use cases. The paper ends with a conclusion and out-look.

# Parallel session 1.5:
# Knowledge and Change Management

## Session Chair:
## Matthieu Bricogne, Université de Technologie de Compiègne, France

3:45pm-
4:05pm

### Estimation of prospective states of mechanical parts for life cycle support

**Hiroyuki Hiraoka, Takeru Nagahata, Hiroki Saito, Tsuramichi Tanigawa**
Chuo University

This paper discusses the life cycle simulation of mechanical parts that are managed by part agents in order to promote their effective reuse.

It is essential to promote reuse of mechanical parts with lifecycle manage-ment for the realization of sustainable society. However, it is difficult to man-age products in use phase of product lifecycle due to the unpredictable and un-controllable behavior of consumers. Authors propose a product lifecycle man-agement system, called part agent system, using network agents and RFID tags attached on parts in order to promote the reuse.

Part agent generates advices for the user on the maintenance of corre-sponding part based on its current state and life cycle information. This paper describes the scheme of life cycle simulation performed by part agents. First, a part agent expands life cycle of the part along time. Next, it estimates by simu-lating the deterioration of the part and then selects preferable maintenance ac-tions. To simulate future states of the part, possibility of events related to the part is estimated based on causal relation of events with acquired data on states of part, user opera-tions and detected events. In this paper, a proposed method is described how the deterioration process is repre-sented as causal relations with probabilities and how the relation is created using simulation. Simulation meth-od is described for two example cases that are fatigue of spring and deteriora-tion of joints of robotic manipulator.

4:05pm-
4:25pm

### PLM Practices for Highly Dynamic and Rapidly Changing Distributed Environments

**Lars Hagge**
DESY, Germany

The European XFEL, a construction project of a large-scale scientific research infrastructure, adopted a PLM solution as the central collaboration and documentation platform in an internationally distributed engineering effort. The project involved the construction of a particle accelerator in novel leading-edge technology. It received contributions from more than 20 institutes in eight European countries, with a total budget of 1.1 B€ and at peak times more than thousand project workers.

The project developed solutions for a number of specific PLM challenges, many of which will also be applicable and beneficial for PLM endeavors in other, industrial environments.The paper investigates the PLM challenges of in-ternational scientific environments and examines how they relate to other, industrial project settings. It introduces solution concepts of general relevance, illustrates their applicability with examples, and analyzes they contribution to the overall organizational maturity.

4:25pm-
4:45pm

### Modular product variety generator based on the modified Genetic Algorithm: a Lego Plane

**Mahmoud Masmoudi1, Mariem Besbes, Marc Zolghadri**
Quartz Laboratory / SUPMECA, France; LA2MP Laboratory / ENIS, B.P 1173, w.3038 Sfax, Tunisia

Mass customization is a business strategy that aims at satisfying individual customer needs and provides them a large product mix. To achieve this goal, it is necessary to manage the product life cycle activities especially the volume and variety of products which have to be easily cus-tomizable. Designing modular products increases the possibility of obtaining customizable products. The modular design consists of breaking down a product into more or less independent sub-elements called modules. This pa-per focuses on setting up a Genetic-based automat-ic product variants genera-tor. The used product as the testbed is a LEGO plane composed of bricks. Different operators are used for selection, crossover and mutation of genes. Each final plane assembly is qualified thanks to some criteria to respect pre-defined constraints. The obtained final assemblies are discussed at the end of the paper to highlights future challenges.

4:45pm-
5:05pm

### Design and manufacturing of a device made of Additive manufacturing machines for fast and reliable measurement of material stiffness.

**Konstantinos Bailas, Paraskevas Papanikos**
University of the Aegean, Greece

Additive Manufacturing (AM) technology is constantly expanding to small and large industry over the last 20 years. The vast potential of this technology has been perceived by many companies which invest in research and development for faster and more reliable machines with better capabilities and more quality products. AM expansion in industry has also been helped by a wide variety of materials, such as polymers, whose technology is developing rapidly with better me-chanical properties related to stiffness and strength. In this paper we will describe a device which can be fully produced by all AM machines and enables users to measure in a fast and reliable way the stiffness of materials without the need for specialized and expensive methods, large-volume laboratory testing machines, specialized technical personnel and time. The objective is to design a small scaled three-point bending device using design intent through a parametric CAD system and manufacture it using AM technology. The device is designed to calculate the deformation and force applied to specific specimens and the Young's modulus of the material. The proposed device and its process helps users to estimate the mechanical properties of materials and apply that information on production or in a simulation system to optimize the printing quality of products by selecting the right material and adjusting the related printing parameters of the machines with the mechanical properties of the produced parts.

5:05pm-
5:25pm

### Motion-Structural Analysis of Systems using Digital Twins

**Sebastian Haag, Reiner Anderl, Klaus Schützer, Eduardo Zancul**
Technische Universität Darmstadt; Methodist University of Piracicaba; University of Sao Paulo

Digital Twins enable the analysis of systems under real world condi-tions using multiphysics models, sensors and bidirectional data connections be-tween the digital and its physical twin. At the Research Lab of the Department of Computer Integrated Design (DiK) of Technische Universität Darmstadt, a Dig-ital Twin demonstrator was de-veloped that enables amotion-structural simulation of a bending beam test bench. The approach provides proof of many of the claimed benefits and challenges through a comprehensible Digital Twin system.

# Parallel session 1.6: PLM Maturity, PLM implementation and Adoption within Industry 4.0

## Session Chair: Louis Rivest, ETS, Canada

Industry 4.0, also called "Fourth Industrial revolution" is upsetting the organizations and industrial tools of enterprises especially SMEs. On the one hand, technologies offer several possibilities, such as digitization; simulation; modelling; communication between people, machines, products and computer systems. On the other hand, customer demand and the market are evolving and becoming increasingly demanding and more complex such as product customization; sales of services around products; connectivity of products and services and finally a major change in the business model.

The digital transformation aims as much to maintain the competitive edge of the SMEs as to anticipate the risks of new competition. To succeed in their digital transformation, SMEs must be able to rely on powerful, agile, innovative ICTs, and especially according to a well-defined approach. In this context, PLM plays a central role in improving internal and external collaboration, production and efficiency of enterprises. Despite the importance of these major challenges, several companies and especially SMEs do not realize the importance of the revolution impact on their ICT/PLM solutions.

SMEs, generally, are not well equipped to adopt and integrate them to their activities. Effectively, several years ago, PLM accounted for very high costs and long and costly internal resources deployments. Therefore, the introduction of the PLM in an organization has an intrusive aspect that may affects the existing organization in its different levels: Strategic, process and tools. Industry 4.0 brought new disruptive technologies (AI, Blockchain, etc.) and processes will definitely impact the PLM implementation.

One important rather recent solution for the above types of problems is various types of maturity – related approaches. A growing attention has been addressed by IFIP WG 5.1 members to PLM implementation, adoption and maturity - related issues, as demonstrated by the increasing number of papers on the topic.

For this session, contributors are challenged to discuss the Impact of Industry 4.0 evolution on PLM through collaboration levels and PLM maturity, the barriers that discourage enterprises from taking advantage of PLM and adoption aspects, strategies and approaches of PLM deployment and implementation.

In order to improve discussions we will involve industrials and professionals. They will share their experience and also participate in discussions and exchanges. Thus, we will allow researchers to have an industrial feedback and explore opportunities for future collaborations.

Topics related to this special session, without being limited to, for instance the following: PLM maturity and PLM evaluation tools; PLM and ICT adoption and adaptation; Impact of digital transformation on PLM; PLM implementation within the Industry 4.0 context.

3:45pm-4:05pm **Evaluating the smart readiness and maturity of manufacturing companies along the product development process**

**Claudio Sassanelli, Monica Rossi, Sergio Terzi.** Politecnico di Milano, Italy

Nowadays, manufacturing industries are compelled to go down the river of Industry 4.0 to either become or remain competitive on the market: in this context digital tech-nologies represent the most important means for manufacturers to drive their trans-formation. However, investing in this kind of technologies could be not enough to go through this transformation in an effective way: manufacturers need to realize their actual digital status and at the same time to evaluate how they support their product development process. In addition, it has not to be neglected the importance of how the process of product development is organized and managed throughout the several functions involved. So far, different methods and maturity models have been pro-posed in literature to help practitioners to evaluate the readiness and maturity of either their smart level or their design and engineering process. Nevertheless, a suitable combination of these tools still needs to be implemented to fully and systematically measure and gauge a company under a PLM and digital perspective: to do this, a case study has been conducted.

4:05pm-4:25pm **PLM Implementation success in SME. An empirical study of implementation projects, preliminary findings.**

**Bas Koomen, Marko Hoogeboom, Vera Schellens.** University of Twente, Netherlands, The; Cadmes b.v., Netherlands, The; Avans University of Applied Science, Netherlands, The

Research on the implementation of Product Lifecycle Management (PLM) has been published since the beginning of the 21st century. Some researchers claim that the success rate of PLM implementation projects is below 50%, but the authors have found no evidence of that figure. In this paper's research, a number of PLM implementation cases have been analyzed for their project goals, implementation challenges, and project results. The research data are retrieved from project files and interviews with project managers. The investigated implementation cases are in Small to Medium-sized Enterprises (SME). The results have been structured and compared with findings from the authors' earlier literature research on SME specific implementation challenges and recommended implementation methods. From this comparison, a conclusion is drawn regarding the implementation success rate and a hypothesis for causes of observed failure.

4:25pm-4:45pm **Towards a novel comparison framework of digital maturity assessment models**

**Bruno COGNET, Jean-Philippe Pernot, Louis Rivest, Christophe Danjou, Thorsten Wuest, Hannu Kärkkäinen, Martin Lafleur**
École de Technologie Supérieure, Montréal, Canada; Arts et Métiers, France; École Polytechnique, Canada; West Virginia University, Morgantown, USA; Tampere University of Technology, Finland; AéroMontréal, Montréal, Canada

The fourth industrial revolution is forcing companies to rethink their status quo – creating a need to assess their digital maturity as a basis for improve-ments. As a result, there is a variety of maturity models available in the literature. This paper introduces a novel comparison framework designed to compare dif-ferent digital maturity assessment models. Our framework has several steps: re-verse engineering of criteria from existing models, criteria matching analysis, as well as computation of the coverage and spread ratios. These two metrics char-acterize respectively the similarity of two maturity models, and the spread be-tween them. We tested the proposed approach with two well-known maturity self-assessment approaches, namely the IMPULS and PwC methods. From our analysis, we were able to derive several insights that will help to develop a new maturity model specifically dedicated to support SMEs in the aerospace industry and manufacturing sector.

4:45pm-5:05pm **Practical Implementation of Industry 4.0 based on open access tools and technologies**

**Ahmed Awouda, Khurshid Aliev, Paolo Chiabert, Dario Antonelli**
Politecnico di Torino, Italy

Industry 4.0 provides a major breakthrough for innovating processes in contemporary manufacturing companies, it arises from the simultaneous presence of an opportunity and a necessity. The opportunity is the availability of powerful ICT technologies, that everyone uses every day with smartphones thanks to the well-established and expensive infrastructure provided by tech giants. The necessity is the achievement of Lean transformation in western enterprises through a deep knowledge of manufacturing processes and an incessant training of the workforce.

Industry 4.0 will provide us with an integrated holistic view of the manufacturing processes and the possibility to control them according to appropriate forecasts and evaluation of performances and results.

Industry 4.0 was born in 2011 and it is in its early stage, there are many research gaps which must be studied and large applications that must be fully integrated into the Industry 4.0 framework.

In this paper, a simple application of Industry 4.0 is presented. It integrates different enabling technologies: Robotics, IoT and fog/edge computing. Moreover, it adopts an open source approach using open access hardware and software tools.

Finally, the proposed framework can serve as an educational and practical tool for demonstration of Industry 4.0.

5:05pm-5:25pm **Implementation of pay-per-output business models and IIoT enabled automation systems in capital goods manufacturing SMEs**

**Mikko Uuskoski, Hannu Kärkkäinen, Karan Menon, Kari Koskinen**
Tampere University, Finland

Manufacturing small and medium enterprises (SMEs) are recognized as a major driving force in European Union (EU) and elsewhere both economically as well as technologically in this ever-changing manufacturing paradigm. SMEs have major difficulties in implementing digital technologies such as the industrial internet enabled technologies that can lead towards a change in the business models, especially towards pay-per-output type business models. In this paper, we have studied pioneering manufacturing SMEs that have implemented pay-per-output business models as well as the related advanced automation systems. Both case companies are able to demonstrate the benefits and difficulties that they faced because of the size (SME) during the implementation process of both the pay-per-output business model and the related advanced automation system.

# Parallel session 3.1: Integration of Inservice and Operation

## Session Chair: Sergei Nikolaev, SKOLTECH, Russian Federation

9:00am-9:20am

### Towards Understanding the role of Product Usage Information in Product Design Improvement

**Quan Deng, Stefan Wellsandt, Karl A. Hribernik, Klaus-Dieter Thoben**
BIBA - Bremer Institut für Produktion und Logistik GmbH, Germany; University of Bremen, Germany

A critical factor that makes a product successful is its acceptance on its market. To achieve this goal, producers oftentimes collect and analyze feed-back information from the market. This information allows them to get a deeper understanding about the product behaviors, customers, their usage patterns, future needs and expectations. The academic literature describes a variety of use cases that outline how development-related tasks can benefit from Product Usage Information (PUI). They differ, for instance, in the investigated product, task, communication channel, information source, and the type of the result. This diversity and the lack of a generally agreed vocabulary in this research domain facilitates a fragmentation of PUI-related research. This paper provides a first systematic overview of a selection of PUI application cases in product design improvement. The study sample consists of 17 research papers from the last 20 years. We characterize and classify the papers mainly through three dimensions: product type, product development phase, and information sources and channels. The results indicate that PUI can support different tasks during product improvement, both in the task clarification phase and in the product conceptual, embodiment and detailed design phases. Our findings suggest that organizations need to know more about PUI-related information sources and channels.

9:20am-9:40am

### Hybrid modelling approach for prescriptive maintenance of gas-turbine power plant

**Sergei Nikolaev, Sergey Belov, Mikhail Gusev, Ighor Uzhinsky**
Skoltech, Russian Federation

The methodology for prescriptive maintenance of complex technical systems is presented. The proposed methodology is based on a hybrid physics-based and data-driven modelling of complex systems. This approach integrates traditional physics-based simulation techniques such as finite-element modelling, finite-volume modelling, bond-graph modelling and data-driven models, with machine learning algorithms. Combined implementation of both approaches results in the development of a set of reliable, fast and continuously updating models of technical systems applicable for predictive and prescriptive analytics. The methodology is demonstrated on the jet-engine power plant preventive maintenance case-study.

9:40am-10:00am

### The Integration of True Lean and Industry 4.0 to Sustain a Culture of Continuous Improvement

**Michael Abbot Maginnis, Buddhika M. Hapuwatte, David Keown**
Institute of Research for Technology Development (IR4TD), Lean System Program, Dept. of Mechanical Engineering, University of Kentucky, Lexington, KY, USA; Institute for Sustainable Manufacturing (ISM), Dept. of Mechanical Engineering, University of Kentucky, Lexington, KY, USA; Toyota Motor Engineering & Manufacturing North America (TEMA), Plano, TX, USA

Recent advances in information and communication technology and the Internet of Things (IoT) are driving the development of Industry 4.0. Its objective is to enable real-time information exchange between people, machines, products and resources, providing new opportunities for improved safety, quality, productivity and cost factors which can be applied in all stages of Product Lifecycle Management (PLM). The application of lean principles and practices where Industry 4.0 is deployed can leverage real-time processing visibility into even greater productivity improvements if implemented correctly. To do this companies need to go beyond the implementation of the familiar lean tools and practices such as 5S, visual management and management directed kaizen activities etc. to consider the thinking behind the tools, especially the role of the team members. An over-reliance on technology risks undervaluing the importance of human innovative capacity which can significantly impact the ability to conduct systematic problem solving, adversely effecting daily operational performance and significantly reducing continuous improvement (CI) capacity. This conceptual paper introduces the major elements and thinking of the Toyota Production System (TPS), also referred to as "True Lean", which are often hidden or underdeveloped within the popular understanding of lean. This paper illustrates how TPS-thinking can be operationalized to support and sustain a CI environment while leveraging the improved visibility possible with Industry 4.0 to integrate all stages of PLM

10:00am-10:20am

### Empirical Study of Multi-party Workshop Facilitation in Strategy Planning Phase for Product Lifecycle Management System

**Satoshi Goto, Osamu Yoshie, Shigeru Fujimura**
Graduate School of Information, Production and Systems, Waseda University; Business Development, PTC Japan Co., Ltd.

This paper proposes a framework of short term and intensive workshop facilitation for multi-party stakeholders in PLM strategy planning phase. We have been empirically pursuing what a valuable facilitation for the workshop is; how multi-party PLM stakeholders can build proactively a mutual consensus in as short a time as possible. PLM project promotion members always encounter a difficulty of consensus building. This is because various stockholders have different opinions and responsibilities through sales, engineering, manufacturing, and service departments. Firstly, we mention key challenges of multi-party consensus building in PLM strategy planning phase. Secondly, we propose a programmatic framework on intensive workshop-facilitation which is configured twelve steps. The key outcome of the workshop is to craft a PLM Success Value Roadmap (PSVR) which is contained various hypothesis defined by the workshop participants helping by facilitators (KPIs). For example, there are PLM vision, strategy, initiative, process, and key performance indicator. Thirdly, we discuss an empirical case study which was deployed our proposed workshop-facilitation method to a specific company; seventeen participants from three different business units were selected. It was held as a two-day intensive PLM trial workshop. Finally, we found that the proposed workshop-facilitation as a consensus building method contributed to the satisfaction of more than 60% of the participants. Of the participants, 85% commented that they would encourage colleagues to participate in the workshop that we have developed. We conclude that the multi-party intensive workshop was a valuable experience that helped that stakeholders to produce a PLM strategy in a relatively short time.

# Parallel session 3.2: Integrating Manufacturing Realities

## Session Chair: Paolo Chiabert, Politecnico di Torino, Italy

9:00am-9:20am

### A concept to integrate Manufacturing Execution and Product Data Management Systems

**Christian Nigischer, Martin Hennig, Detlef Gerhard**
TU Wien MIVP, Austria

Variant rich production of individualized products and customer solutions results in new challenges for all involved industrial information systems in a producing company. To keep pace with the new requirements of a volatile future market and exploit benefits of flexible digital production environments, it is crucial to adapt integration concepts of Industrie 4.0, e.g. enhance information exchangeability by improving interconnectivity between software solutions, utilize all sources of data from a products production and use phase, and maintaining an up-to-date digital twin of the product and production assets.

This paper presents an integration concept for the interaction between Product Data Management (PDM) systems Manufacturing Execution Systems (MES), and shop floor level client systems. It addresses the gap of information flow be-tween the different involved key software tools in a twofold manner. On the one hand side, specific information gained from production and use phase data of products have to be looped back to the PDM system. This sets the foundation for a better understanding of production planning and execution as well as use phase issues related to the engineering phase where problems have to be addressed for continuous product improvement. On the other hand side, a direct information flow from PDM to MES and shop floor clients is defined to enable forwarding of current variant product instance information. To evaluate the practical applica-bility and additional value of the developed integration concept, a case study with an industry partner is conducted.

9:20am-9:40am

### Robot Coalition Formation Based on Fuzzy Cooperative Games Over Blockchain-based Smart Contracts

**Alexander Smirnov, Leonid Sheremetov, Nikolay Teslya**
SPIIRAS, Russian Federation; Mexican Petroleum Institute

In production cyberphysical systems robots perform most operations. On the way to Industry 4.0 robots have to be automated and perform operation in coali-tion to reach common goals. The paper describes an approach to dynamic for-mation of coalitions of independent robots based on the integration of fuzzy co-operative games and smart contracts. Each robot is viewed as an independent agent, negotiating and bidding with others during the coalition forming for distri-bution of joint winnings. It is necessary to choose a combination of robots from a large number of potential participants in way to maximize efficiency of joint work, while the efficiency of the entire coalition is unknown before-hand. A co-operative game with fuzzy core is used to form a coalition of robots allowing co-ordinating the actions of individual members to achieve a common goal, as well as to evaluate and distribute the overall benefit. To implement the negotiation pro-cess and record the composition of the coalition and the responsibilities of indi-vidual participants, it is proposed to use the smart contract technology, which now become a part of the blockchain technology. Smart contracts are proposed to be used as entity holding requirements and expected winnings of each participant in the immutable structure of a blockchain network. The final agreement can also be stored by all participants in form of smart contract that contains the distribution coefficients of the winnings given all the conditions of participation in the coa-li-tion. The availability of smart contracts to all participants in the coalition makes it possible to ensure joint control over the fulfillment of the task assigned to the coalition.

9:40am-10:00am

### Integration between PLM and MES for one-of-a-kind production

**Emiliano Traini, Giulia Bruno, Ahmed Awouda, Paolo Chiabert, Franco Lombardi**
Politecnico di Torino, Italy

Despite the amount of research addressing the formalization of product-related knowledge, the practical use of tools for knowledge management is still very low at the corporate level. Several commercial software applications are already available for product lifecycle management (PLM) and manufacturing execution system (MES). Unfortunately, these two applications are scarcely integrated thus preventing an efficient and pervasive collection of data and the consequent creation of useful information. This is more critical in One-of-a-kind Production (OKP), where each product is unique, the process is not completely defined at the design stage, but it is continuously improved at the shop floor level by skilled operator. In such situation most of the company's knowledge relies on the lessons learnt by operators in years of work experience, and their ability to reuse this knowledge in order to face new problems. Because OKP must devel-op unique product and complex processes in short time, it is mandatory to reuse the acquired information in the most efficient way. It is therefore necessary to collect all the data from the shop floor and transform them in information that will be used in the development of the next product and process. The aim of this paper is to design a framework able to integrate data, from both design and manufacturing phases. To this aim, a framework has been designed to structure and relate information from the PLM and the MES systems. A case study has been developed for a car prototyping company to prove the efficiency of the proposed solution.

10:00am-10:20am

### Current Issues to achieve the Semantic Interoperability with heterogeneous information and knowledge to support the Manufacturing Process

**Taina da Rocha, Anderson Luis Szejka, Osiris Canciglieri Junior**
Industrial and Systems Engineering Graduate Program, Pontifical Catholic University of Para-na, Brazil

The strong competitiveness challenges manufacturing industry to discover news ways to bring new products or im-prove their manufacturing process. The across the manufacturing process thousands of heterogeneous data must be shared and this data must be translated in information and knowledge to support the manufacturing quality control. It is fundamental that the meaning associated to each information must be shared in an explicit and an understand-able way. Semantic interoperability explores the ability of computer systems to share information and knowledge in unambiguous way. This work aims to understand the current issues relating to the heterogeneity of information and knowledge to the semantic interoperability across the manufacturing systems. This objective will be achieved through a bibliographic review of works and studies carried out in the area of Semantic Interoperability, Decision-Making Systems, Information Heterogeneity, Ontological Rules and Multiple Domains. This research showed through the formalization of information and knowledge obtained from multiple phases of manufacturing systems and shared in an interopera-ble environment, even though it is heterogeneous, it is possible to have higher quality in the interpretation and sharing information and knowledge, avoiding mistakes and misinterpretation of communication between different domains.

# Parallel session 3.3: System/Product Life Cycle

## Session Chair: Grant McSorley, University of Prince Edward Island, Canada

9:00am-9:20am **Disassembly Process Planning under End-of-Life Product Quality**

**M.-Lounes Bentaha, Alexandre Voisin, Marangé Pascale**
Université Lyon 2, DISP Laboratory (EA 4570), Lyon, France; Université de Lorraine, CRAN, UMR CNRS 7039, Nancy, France

Quality of post-consumer products is one of the major sources of uncertainty in disassembly systems. This paper presents a decision tool for disassembly process planning under variability of the End-of-Life product quality. The objective is to maximize the profit of the disassembly process. This latter is the difference between the revenue generated by recovered parts and the cost of the disassembly tasks. The revenue of a product (subassembly, component) depends on its quality. The proposed approach helps to take decisions about the best disassembly process and the depth of disassembly, depending on the quality of the products to be disassembled. Industrial applicability and interest are shown using an industrial case focused on the remanufacturing of mechatronic parts in the automotive industry.

9:20am-9:40am **An approach to assess engineering change effort retrospectively utilizing past engineering change information**

**Niklas Kattner, Eldar Shakirov, Udo Lindemann**
Technical University of Munich, Germany; Skolkovo Institute of Science and Technology, Russia

The competitiveness of companies is nowadays highly dependent on an efficient product development. Shorter time to market, increased competition as well as ac-celerated market dynamics can be handled well by a continuous improvement in development efficiency. Hence, improving the development performance can have a big impact on the time to market. However, an increasing number of re-sources must be assigned to the management of engineering changes. The man-agement of changes strongly influences the resources available for the actual de-sign process. Furthermore, the increasing complexity of technical systems as well as the organization affects the engineering change situation and further induces change complexity. This paper therefore introduces a methodology to retrospec-tively assess engineering change information to identify areas for reducing the change workload. It therefore introduces a procedure to guide users through the process of the assessment. Furthermore, it suggests measures to evaluate the change situation regarding the induced workload. Finally, it introduces a tool to automatically calculate the measures and therefore supports users in the assess-ment.

9:40am-10:00am **Product-Service Systems lifecycle management in industry: interests and exploited data**

**Juliana Cavalcante da Silva, Lilia Gzara**
Laboratory G-SCOP - Grenoble INP, France

Product-Service Systems (PSS) emerged, among other reasons, as a response to the market's demand for specific solutions to meet their needs in a competitive and sustainable way. In order to manage and improve this value offered to the customer, lifecycle information needs to be gathered and exploited. In this paper, we present a survey realized among PSS providers, aiming to identify the exploitations and anticipations serving best the industry's current needs and interests. These exploitations were divided in five categories, which the respondents were invited to rank according to the pertinence to their business. The survey also covers the investigation of which data the providers dispose to achieve these exploitations. The answers were analyzed and compared to general information about the PSS offered by the respondents, such as the type of PSS, product smartness level and type of services offered. The survey results point to an initial stage of PSS development, with an important potential and interest to improve. The analysis developed in this work will further guide the proposition of an information system architecture for PSS lifecycle management in closed-loop, which should integrate the exploitations highlighted by the survey respondents.