# SOHOMA

2021

Cluny, France
November, 18-19

## 11th Workshop
SERVICE ORIENTED, HOLONIC AND MULTI-AGENT MANUFACTURING SYSTEMS FOR INDUSTRY OF THE FUTURE


Arts et Métiers Sciences et Technologies

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Book of Abstracts of the International Workshop

# SOHOMA'21

# Service Oriented, Holonic and Multi-Agent Manufacturing Systems for Industry of the Future

November 18-19, 2021

Cluny, France

*Editors:*

**Laurent JOBLOT Arts et Métiers Institute of Technology**

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# About the Workshop

It is our pleasure to invite you to participate in the 11th International Workshop on Service Oriented, Holonic and Multi-Agent Manufacturing Systems for Industry of the Future - SOHOMA'21, organized by the Arts et Metiers Institute of Technology of Cluny (https://artsetmetiers.fr/en/campus/cluny) in collaboration with University Politehnica of Bucharest (the CIMR Research Centre in Computer Integrated Manufacturing and Robotics), Polytechnic University Hauts-de-France (the LAMIH Laboratory of Industrial and Human Automation Control, Mechanical Engineering and Computer Science) and Polytechnic Institute of Bragança (the CeDRI Research Centre in Digitalization and Intelligent Robotics). The SOHOMA'21 workshop has the scientific support from the IEEE-IES Technical Committee on Industrial Agents (https://tcia.ieee-ies.org/), from the GdR-MACS of the CNRS (https://gdr-macs.cnrs.fr/) and from the General Association of Engineers in Romania AGIR (https://www.agir.ro/).

The main objective of SOHOMA Workshops is to foster innovation in smart and sustainable manufacturing and logistics systems and in this context to promote concepts, methods and solutions for the digital transformation of manufacturing through service orientation and agent-based control with distributed intelligence.

SOHOMA 2021 will take place in Cluny – France, at the Arts et Metiers Institute of Technology of Cluny, on 18-19 November 2021

# The Workshop's theme

The theme of the SOHOMA'21 Workshop is "Convergence of factory asset and process lifecycle with product lifecycles in Cyber-Physical System - based production".

Products conceived and designed to be embedded with computational and intelligent power and thus to be "smart" both in production and utilization phases are able to exchange information within and beyond the limit of the factory. These smart products are connected with factory assets and processes in the supply networks and can provide a new type of interaction, enabling collaborative demand and supply planning, traceability, and execution.

Cyber-Physical Systems (CPS) take advantage from the integration of Cloud-based and Service-Oriented Architecture to deploy end-to-end support along both product lifecycles (including after sales services, maintenance and upgrade along the usage cycle, a.o.) and factory lifecycle. On the factory lifecycle perspective, CPS are able to interact with all the hierarchical layers of the automation pyramid - from field level to ERP - and to empower the exchange of information across all the process and service stages, resulting in a better product-service development. This will allow the value network alignment with the customers' changing needs and optimization from different perspectives (quality, time to market, costs, sustainability goals, etc.)

Transforming industry with intelligent end-to-end solutions and the shift to smart manufacturing has generated innovations in automation, robotics and the Industrial Internet of Things (IIoT). Introducing artificial intelligence (AI) and machine learning (ML) technologies, interoperability and secure connectivity enables real-time monitoring, control and optimization of processes, resources and systems – leading to greater productivity, increased safety and reduced costs.

The research of the SOHOMA scientific community is aligned to the actual trends and development priorities for CPS in the manufacturing and supply chain industries:

A. Future industrial systems will be conceived as Cyber-Physical Systems that use strongly coupled virtual entities (software agents, holons or virtual twins) which represent (are embedded in) physical components that sense,

actuate, process, control, compute and communicate through several networks including the Internet in order to reach global goals - making products, delivering services efficiently and safely. The drivers of industrial CPSs are resource and product virtualization, and distribution of intelligence in IT systems that virtualize workloads through cloud services. MES virtualization will reduce operational costs and improve flexibility, agility, reconfigurability and maintainability of the production system.

B. The factory data streams and global MES functions will be mapped to specific workloads in the cloud, defined in terms of activity scheduling, resource assignment and behaviour forecast; the latter incorporate AI and ML capabilities. The industrial sector is interested in deploying autonomous workloads to achieve higher productivity and better operational safety.

C. Autonomous workloads, supported by AI and other innovative technologies, are predicted to be-come the most pervasive workloads across the industrial sector.

D. Manufacturing as a Service (MaaS) - the new models of service-oriented, knowledge-based manufacturing systems optimized and reality-aware, virtualizing and encapsulating shop floor and MES workloads into cloud networked services - will also address "product design for open manufacturing", a vision of knowledge and infrastructure sharing in cloud networked enterprises.

This 11th SOHOMA edition puts the focus especially on how the core processes, systems and related software tools existing on the market - PLM, PLC, SCADA, MES, ERP - and under development - Industrial CPS and IoT- are interconnected and orchestrated in order to create a product-service centric closed loop collaboration covering the design, engineering, production and after-sales phases in the manufacturing value chain of the future.

This approach derives from the research performed in the last years in the scientific community SOHOMA, which uses recently developed *key digital technologies* - cloud and fog computing, digital twins, edge computing, digital control and optimization, robotics, machine vision, additive machining, Artificial Intelligence and machine learning:

- Data mining and real time analysis to design new product service systems accelerating the propagation of the servitisation, and redesigning business models for ecosystems of product-service starting from data collected during the utilization phase.
- Smart technologies and smart connectivity in factories, i.e. the digital integration of manufacturing and logistic equipment in terms of information, communication and automation technologies.
- CPS-enabled reconfiguration of automated manufacturing systems: (1) Deployment of legacy production equipment and systems; (2) Increasing autonomy and intelligence of existing machinery and robots; (3) Adaptation through context awareness and reasoning aiming at making machinery and robots aware of their surroundings; (4) Developing a multi-layered, decentralized control architectures in which resources can take autonomous decisions.
- Intelligent decision making in cloud manufacturing through big data streaming and machine learning; combining data-driven digital twins for predictive situation-awareness with model-driven digital twins simulating the reality of interest faster than real-time with software in the loop.
- Sharing of data/information from all the supply chain's elements to support continuous monitoring and automatic control of all the production phases while preserving security and confidentiality of data shared along the supply chain.
- The adoption of IoT and CPS as enablers of product servitisation allowing to track the product and services along the whole lifecycle and consequently enhance customers' satisfaction.
- Service Manufacturing which includes design for open manufacturing, optimization, maintenance, supply and distribution activities, all of them being offered in the "as a Service" option. service manufacturing was proposed.
- Fostering the open manufacturing enterprise - responsive to the X-as-a Service model, where X covers design, manufacturing, supply, and distribution, and supports resource sharing and networking.

Papers presenting solutions based on these technologies for new applications in the manufacturing value chain at the confluence of information technology and automation are especially welcome. All contributions must indicate alignment with the workshop's theme.

# Workshop topics

The papers presented at the SOHOMA 2021 Workshop will cover the following topics:

- Modelling of discrete event dynamic industrial systems
- Multi-Agent Systems and control with distributed intelligence in industry
- Product intelligence: concepts, architectures, implementation, use cases
- Holonic Manufacturing Execution Systems
- Intelligent Manufacturing Systems
- Dynamic and green infrastructure for sustainable manufacturing
- Mixed production planning and scheduling
- Virtual factory, networked supply chains and customer-oriented logistics
- Manufacturing Integration Framework
- Digital Twins with resource and product virtualization
- Edge and Fog Computing for Industrial Internet of Things
- Industrial Internet of Things / Physical Internet
- Cloud Manufacturing and resource virtualization
- Computing and Service Oriented manufacturing
- Servitization and Product-Service Systems
- Swarm intelligence in manufacturing
- Multi-robot systems in manufacturing, control and applications
- Bio-inspired theories for smart manufacturing and evolutionary robotics
- Big Data steaming and the contextual enterprise
- Artificial intelligence and machine learning in large scale manufacturing
- Predictive resource health monitoring and maintenance
- Cyber-Physical Production Systems and Industry 4.0
- Manufacturing as a Service, product design for open manufacturing
- Digitalization of supply chains and Logistics 4.0
- Performance evaluation of industrial emerging behaviour
- Holonic hybrid supervised control of industrial processes
- Humans in Industry 4.0
- Ethics of autonomous intelligent systems


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# Program briefly

# Program at a glance

# Provisional program

## 17th November 2021

| | |
|---|---|
| 5.30 - 6.30 pm | Welcome & Registration - *Room Fontaine* |

## 18th November 2021

| | |
|---|---|
| 8.00 - 9.00 am | Registration |
| 9.00 - 9.20 am | Opening Session - *Amphitheater*<br>Michel Jauzein (Director Arts et Metiers Institute of Technology, Cluny) |
| 9.20 - 10.40 am | Session A: **Humans-Systems Integration in Industry 4.0 environments** - *Amphitheater* |
| 10.40 - 11.00 am | Coffee Break |
| 11.00 - 12.40 am | Session B1: **Industry of the Future: ethics** - *Amphitheater*<br>Session B2: **Reconfigurable Manufacturing Systems** - *Room Bernon* |
| 12.40 - 2.00 pm | Lunch - *Self* |
| 2.00 - 3.00 pm | **KEYNOTE 1**<br>**Radu Babiceanu / Embry-Riddle Aeronautical University**<br>**Secure Digital Manufacturing and Supply Chain Operations:**<br>**An Artificial Intelligence Approach**<br>*Amphitheater* |
| 3.00 - 4.00 pm | Session C: **Multi-agent and holonic approaches in smart manufacturing Part 1** - *Amphitheater* |
| 4.00 - 4.20 pm | Coffee Break |
| 4.20 - 6.20 pm | Session D1: **Digital Twins in Cyber-Physical Industrial Systems** - *Amphitheater*<br>Session D2: **Efficient and intelligent monitoring and control of industrial systems** - *Room Bernon* |
| 7.30 - 8.30 pm | Optional wine degustation |
| 8.30 pm | Gala Dinner<br>*Hostellerie d'Héloise, 7 Rue de Mâcon 71250 Cluny* |

## 19th November 2021

| | |
|---|---|
| 8.00 - 8.30 am | Registration |
| 8.30 - 9.40 am | Introduction of Jean-Rémy Chardonnet (Institut Image Chalon-sur Saône)<br>**KEYNOTE 2**<br>**E.Rother/ General Manager FPT Powertrain Technologie, France**<br>**I4.0 Road Map creation. Case Study in a 147-years-old plant**<br>*Amphitheater* |
| 9.40 - 10.40 am | Session E: **Multi-agent and holonic approaches in smart manufacturing Part 2** - *Amphitheater* |
| 10.40 - 11.00 am | Coffee Break |
| 11.00 - 1.00 pm | Session F1: **Digital manufacturing** - *Amphitheater*<br>Session F2: **Intelligent control for a Sustainable and Efficient supply chain of the future** - *Room Bernon* |
| 1.00 - 1.10 pm | Closing Session - *Amphitheater* |
| 1.10 - 3.00 pm | Lunch - *Self* |
| 3.00 - 4.30 pm | Optional visit of the Abbey - *Meeting point Room Fontaine* |

# Detailed program

# Keynote Speaker

## 18th November 2021, 14h - 15h00

### *Secure Digital Manufacturing and Supply Chain Operations: An Artificial Intelligence Approach*

***Keynote 1*** : **Radu Babiceanu, Ph.D.**
Interim Chair and Professor of Systems Engineering
Department of Electrical Engineering and Computer Science
Embry-Riddle Aeronautical University, 1 Aerospace Blvd., Daytona Beach, FL 32114
Office: 386-226-7375 | babicear@erau.edu | https://faculty.erau.edu/Radu.Babiceanu

- Securing digital transactions is critical for all industry sectors. Manufacturing and supply chain operations are central for all industry sectors from aviation and aerospace to pharmaceuticals, and to grocery stores items. Resilient cybersecurity protections for these operations call for a holistic and crosscutting approach to proactively address both real-time and persistent cyber-threats in several operational areas to protect design data, networks, additive manufacturing files, field loadable software, and command and control systems to support continued uninterrupted operations. Recent advances in Artificial intelligence (AI), specifically in the data-driven Machine Learning (ML) domain resulted in leap expansions of several industry sectors. This talk discusses the adoption of AI approaches to safeguard against malicious actors carrying out increasing and more sophisticated, individual or coordinated cyber-attacks. Autonomous and semi-autonomous cybersecurity, applications of game theory, human-AI interfaces, predictive analytics, and trustworthy AI are discussed, and their application for securing digital manufacturing and supply chain operations are presented.

***Short biography****: Dr. Radu Babiceanu is the Interim Chair and a Professor of Systems Engineering with the Department of Electrical Engineering and Computer Science at Embry-Riddle Aeronautical University (ERAU) in Daytona Beach, Florida. Dr. Babiceanu received his Ph.D. degree in Industrial and Systems Engineering from Virginia Tech in 2005, and previously served on the faculty at the University of Arkansas at Little Rock. At ERAU, Dr. Babiceanu teaches systems engineering courses, such as System Architecture Design, System Quality Assurance, and System Safety and Certification. He also developed and delivered short training courses for industry in the area of aircraft system safety engineering and certification. His research interests are in the aviation/aerospace operational ecosystem, with emphasize in cybersecurity and safety-critical systems assurance, formal modeling and verification, and AI/ML approaches to enhanced operations.*

# 19th November 2021, 8h45 - 9h45

## *I4.0 Road Map creation. Case Study in a 147-years-old plant.*

**Keynote 2 : Eva Rother, PhD.**

**General Manager FPT Powertrain Technologie, France**

- I4.0 concepts are mainly presented and discussed in an academic point of view. Links between research and concrete applications are less usual. In a centenary factory, having to renew the technological challenges to remain at the level expected by its customers and shareholders, creation and implementation of an I4.0 roadmap is a relevant and exiting challenge. This keynote will presented an unexpected aspect of the 4th industrial revolution with constraints, priorities, failures and successes, mainly focused on the on the most important but often overlooked, factor : human and technical heritage.

***Short biography**: Industrial engineer, passionate by the reality of the manufacturing life and the management, Eva shares activities between the workshop of the biggest factory in Burgundy and the academic world in LIRIS and INSA of Lyon. After 15 years in different automotive company, she joined LIRIS laboratory and facilitated the access of the factory to young researchers. This innovative and research team, contribute to the expansion of I4.0 mindset and technology in the plant, linking with the traditional lean improvement. Thanks to this contribution, and the effort of all the employees, FPT France received many awards in an international level.*

# Technical Session A

*18th November 2021, 9h20-10h40*

*Amphitheater & Channel MS Teams 1*

## Humans-Systems Integration in Industry 4.0 environments

*Chair: Karel Kruger*

**Classification of Technical Challenges to Human-System Integration in Cyber-Physical Systems.**

*TW Defty, K Kruger, AH Basson*

**Effective human integration in modern manufacturing environments: A problem of Administrative Logistics.**

*Dale Sparrow, Karel Kruger and Anton Basson*

**Evolution of the human digital representation on manufacturing production systems.**

*Perez Monica-Juliana, Sebastian-Mateo Meza, Flor-Angela Bravo, Jose-Fernando Jimenez, Damien Trentesaux*

**Modelling Human and Artificial Entities for Cyber-Physical Production and Human Systems Cooperation.**

*Gabriel Zambrano Rey, Marie-Pierre Pacaux-Lemoine*

- ***18th November 2021, 9h20-10h40****. Technical Session A - Amphitheater (&Teams 1)*
  ***Humans-Systems Integration in Industry 4.0 environments***
  Chair: Karel Kruger,

**Abstract**: The fourth industrial revolution promises enhanced connection between smart systems and people. While research has mainly focussed on developments in automated systems, there has been a growing interest in the role(s) of humans within such industry 4.0 environments. The challenges of mutual integration between humans and systems have also captured the interest of the SOHOMA community, with special sessions arranged around this topic in the recent editions of the workshop. Similarly, this session will serve as a forum emerging interdisciplinary research relevant to human-system integration and organization and its applications within the Industry 4.0 context..

**Key words**: Human factors; human-system integration; human-machine cooperation; human resource management; ergonomics; Industry 4.0

9h20 - A1 - **Classification of Technical Challenges to Human-System Integration in Cyber-Physical Systems**

TW Defty, K Kruger∗, AH Basson
Department of Mechanical and Mechatronic Engineering, Stellenbosch University, South Africa, 7600
∗kkruger@sun.ac.za

**Abstract**: Production strategies that improve the automation and digitization of production operations have led to complex intelligent manufacturing systems in the fourth industrial revolution. Therefore, Human-System Integration (HSI) research has focused on human considerations within these complex systems. Human Cyber-Physical Systems (HCPSs) have been developed to support the shift in manufacturing from technology-focused to sociotechnical-focused. Nevertheless, challenges continue to limit the realization of integrated HCPSs. This paper proposes a classification framework to map the various systems, interactions and functions associated with HSI in HCPSs. The framework is based on *representation*, *communication* and *interfacing*, as three key aspects of effective HSI. Using the framework, technical challenges for HSI in CPSs are identified.

**Key words**: Human System Integration ; Human Cyber Physical Systems ; Human Digital Twin ; Intelligent Manufacturing Systems

9h40 - A2 - **Effective human integration in modern manufacturing environments: A problem of Administrative Logistics**

Dale Sparrow, Karel Kruger(∗) and Anton Basson
Department of Mechanical and Mechatronic Engineering, Stellenbosch University, Stellenbosch 7600, South Africa
∗kkruger@sun.ac.za

**Abstract**: Integration of humans into modern factory environments is complex due to differences in communication and coordination methods between digital and human entities. In order to evaluate aspects of this integration that need to be improved or evaluate how different methods compare in effectiveness, the concept of Administrative Logistics is discussed. The concept of Administrative Logistics is developed from a first principles basis of organizing, managing, and executing tasks using organizational resources as described by Herbert Simon, and is the basis for a set of metrics used to evaluate the effectiveness of a system at integrating humans with modern factory environments.

**Key words**: Human integration ; Human systems integration ; Industry 4.0

10h – A3 - **Evolution of the human digital representation on manufacturing production systems**

Perez Monica-Juliana[1], Sebastian-Mateo Meza[2], Flor-Angela Bravo[1], Jose-Fernando Jimenez[1], Damien Trentesaux[3]
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LAMIH UMR CNRS 8201, Université Polytechnique Hauts-de-France, F- 59313 Valenciennes cédex 9

59313 Valenciennes CEDEX 9 - France

**Abstract**: The fourth industrial revolution has brought significant changes to the economic and societal world. In the manufacturing context, this revolution allows improving the efficiency and productivity of manufacturing operations through the deployment of technological advances. One of the main concerns of society is the human well-being in the workplace environment. Despite the advances in the manufacturing domain, humans will continue to have certain level of involvement in manufacturing operations. Still, for an adequate human-system synchronization, it is needed to understand the human representation, interaction, and contribution on advanced manufacturing systems, without threatening the human well-being. For this reason, this paper reviews the role of the human operator, examining the representation, interaction, involvement, and capabilities of the human in manufacturing systems. This exploratory research analyses the evolution of the human operator, considering the type of human inclusion, the human/virtual-environment communication, the human factors indicators, the virtual representation, the purpose of the virtual representation and the devices/measurements of human factors.

**Key words**: Industry 4.0 ; human virtual representation ; manufacturing ; digital twin ; cyber ; physical system

10h20 – A4 - **Modelling Human and Artificial Entities for Cyber-Physical Production and Human Systems Cooperation**

Gabriel Zambrano Rey[1], Marie-Pierre Pacaux-Lemoine[2]
1 : Associate Professor, Pontificia Universidad Javeriana
Carrera 7 #40-62 Edificio Jose Gabriel Maldonado Facultad de Ingeniería - Colombia
2 : Laboratoire d'automatique et de mécanique industrielles et humaines (LAMIH) -
CNRS : UMR8530, Université de Valenciennes et du Hainaut-Cambrésis
LE MONT HOUY 59313 VALENCIENNES CEDEX 9 - France

**Abstract**: To successfully tackle the Industry 4.0 (I4.0) paradigm, automation technolo-gies must be seen and used to further enhance, complement and/or augment the human's capabilities rather than replacing human competences. Cyber-Physical Production and Human Systems (CPPHS) acknowledge human presence, be-haviors, creativity and skills, considering human beings as inherent elements of manufacturing control systems. Nevertheless, to empower industrial applica-tions of CPPHS, cooperation is necessary to deal with complex interactions, appropriate and context-aware entity abstractions, define and implement com-munication protocols and interfaces. This paper focuses on the CPPHS Concept Definition Phase by proposing a common entity abstraction that can be instanti-ated to model human and artificial entities. Our purpose is to offer an entity model in which cooperation becomes natural because it is rooted in the entity's design and implementation. This work is inspired by the fact that in most of the literature reviewed on CPPHS, there are few details on the design of digital en-tity representation and their functionalities, with an emphasis on cooperation between such heterogeneous entities human. Although this paper focuses on the conceptual definition phase, this phase is extremely relevant to build effective cooperation within CPPHS, starting with modelling their constituent elements.

**Key words**: Cyber; Physical Production Systems ; Humans in Industry 4.0 ; Multi ; Agent Systems ; Holonic Manufacturing Systems

# Technical Session B1

*18th November 2021, 11h00-12h40*

*Amphitheater & Channel MS Teams 1*

## Industry of the Future: ethics

*Chair: Trentesaux Damien*

**Advancing an Artificial Intelligence Ethics Framework for Operator 4.0 in Sustainable Factory Automation.**

*Donna Burnett, Nicole El-Haber, Damminda Alahakoon, Stamatis Karnouskos, Daswin De Silva*

**A vision of applied ethics in industrial cyber-physical systems**

*Damien Trentesaux, Emmanuel Caillaud, Raphaël Rault*

**A framework fostering the consideration of ethics during the design of industrial cyber-physical systems.**

*Damien Trentesaux, Emmanuel Caillaud, Raphaël Rault*

**Ethical principles in Industry 4.0 automated decision-making systems.**

*Odile Bellenguez, Olivier Cardin, Toinon Vigier, Colin De La Higuera*

**Cripping assistive tech design: How the current disability framework limits our ability to create emancipatory technology.**

*Enka Blanchard*

- ***18th November 2021, 11h00-12h40**. Technical Session B1 - Amphitheater (&Teams 1)*
  ***Industry of the Future: ethics***
  Chair: Trentesaux Damien

**Abstract**: **This session, supported by the IEEE IES Technical Committee on Technology Ethics and Society (TC-TES https://tes.ieee-ies.org/), is intended to serve as the basis for the construction of a special issue of the Elsevier Journal Computers in Industry, willing to address this topic. Extended versions (including new results, new figures…) of papers composing this special session will be invited to be submitted to the special issue of the journal**.

Based on the development of Artificial Intelligence models and methods, Future industrial systems will be based upon the design and use of more autonomous, intelligent systems, being resources, products, digital systems interacting or cooperating with humans. This holds also true in the healthcare, logistics and transportation sectors. All these developments should be accompanied by strong attention to ethical and societal issues involved in the design, development, operation and maintenance of such systems and their automation beyond classical key performances indicators expressed in terms of effectiveness or efficiency.

This session is seeking position papers, ideas, interdisciplinary works, critical analysis and comparison, simulations, even with a low degree of maturity. All aspects relevant to ethics can be addressed: ethical behaviour of researchers (ethical design of systems, techno-ethics), study of the ethical behaviour of the artificial system designed (design of ethical systems, machine ethics), impact on society, ethical risks relevant to the over-integration of humans with artificial systems (e.g., operator 4.0), algorithmic bias in AI, and transparency in intelligent autonomous systems and their applications, performance measurement,

etc. Interdisciplinary studies on the applicability of different ethical and societal frameworks in future industrial systems, including legal and economic aspects are also of great interest. The impact on logistics as well as on legal and societal aspects can be considered as an interesting starting point for proposals. Inspiration from sci-fi literature, philosophy and other fields relevant to humanities would bring interesting complementary points of view...

**Key words**: ethics, human-machine cooperation, system engineering, artificial intelligence, safety, bias and transparency, technology, society

11h - B11 - **Advancing an Artificial Intelligence Ethics Framework for Operator 4.0 in Sustainable Factory Automation**

Donna Burnett[1], Nicole El-Haber[1], Damminda Alahakoon[1], Stamatis Karnouskos[2], Daswin De Silva[1]
1 Centre for Data Analytics and Cognition, La Trobe University, Victoria, Australia.
2 Research, SAP, Walldorf, Germany

**Abstract**: The success of Industry 4.0 has led to technological innovations in Operator 4.0 roles and capabilities. This increasing human presence and involvement amongst Artificial Intelligence (AI) solutions, automated and autonomous systems have renewed the ethics challenges of human-centric industrial cyber-physical systems in sustainable factory automation. In this paper, we aim to address these ethics challenges by proposing a new AI ethics framework for Operator 4.0. Founded on the key intersecting ethics dimensions of the IEEE Ethically Aligned Design and the Ethics Guidelines for Trustworthy AI by the European Union's High-Level Expert Group on AI, this framework is formulated for the primary profiles of the Operator 4.0 typology across transparency, equity, safety, accountability, privacy, and trust. This framework provides a level of completeness, where all ethics dimensions are closely intertwined, and no component is applied in isolation for physical, mental, and cognitive operator workloads and interactions.

**Key words**: Operator 4.0, Industry 4.0, Factory automation, AI Ethics, Machine ethics, Artificial Intelligence

11h20 – B12 - **A vision of applied ethics in industrial cyber-physical systems**

Damien Trentesaux[1], Emmanuel Caillaud[2], Raphaël Rault[3]
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**Abstract**: Industrial cyber-physical systems integrate learning capacities and are intended to interact and cooperate with humans. These characteristics contribute to their complexity and harden their engineering process. More, their evolving knowledge increases the difficulty of their validation during research and development stages. In this paper, the difficulties encountered during the engineering of these systems are underlined. A specific focus is set on ethical considerations, which must be addressed along their design and use. We study more precisely the application of ethical paradigms and types in the context of industrial cyber-physical systems. An overview of the main approaches is proposed and a vision of what could be the concept of applied ethics in industrial cyber-physical systems is suggested. From that vision, a set of questionings regarding different stakeholders is constructed as an illustration. This proposal shows the diversity and the complexity of the ethical questions, which could help raising the awareness of researchers, designers and engineers working on Industrial cyber-physical systems.

**Key words**: Industrial CPS ; applied ethics ; lifecycle

11h40 – B13 - **A framework fostering the consideration of ethics during the design of industrial cyber-physical systems**

Damien Trentesaux[1], Emmanuel Caillaud[2], Raphaël Rault[3]
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**Abstract**: A framework fostering the consideration of ethics during the design of industrial cyber-physical systems is proposed. This framework considers the whole lifecycle of industrial cyber-physical systems. It has been constructed through three dimensions which are the subject, the requester and the time. An application of this framework, Dathali16, is presented. Dathali16 enables the identification of ethical risks of future industrial cyber-physical systems, as a first step towards their mitigation. Even at its early stage of development, the potential benefits of Dathali16 to help identify and mitigate ethical risks are clearly pointed out. It also illustrates how the proposed framework can be used by researchers wishing to pay attention to ethics during their design. The proposed framework remains to be improved but can be used in other contexts such as the definition of ethics-aware products and services.

**Key words**: ethical framework ; industrial cyber physical systems ; design ; lifecycle

12h – B14 - **Ethical principles in Industry 4.0 automated decision-making systems**

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**Abstract**: Decision making is one of the main elements currently questioned in Industry 4.0. It is meant to be efficient, fast, agile, but the questions of ethical principles is rarely included in the studies of literature. This communication first investigates the classical computer-based decision-making process in Industry 4.0, and exhibits the main flaws of such a process on an ethical point of view. An analysis of the main philosophical intellectual currents on the topic shows that three schools among

them would actually be competing and coexisting in an eth-ical decision-making process. The integration of these currents in the decision-making process is finally illustrated by two industrial examples
**Key words**: ethics ; industry 4.0 ; decision making ; utilitarianism ; virtue ; deontologism

12h20 – B15 - **Cripping assistive tech design: How the current disability framework limits our ability to create emancipatory technology**

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**Abstract**: Recent advances in assistive technologies have blurred the lines between compensating for impairments --- for disabled users --- and augmenting capabilities --- such as with cobotic systems. This article examines how assistive technologies generally seek to compensate for a single deficiency, as opposed to being more generalist tools meant to improve the lives and autonomy of (not necessarily) disabled users. It starts with a brief presentation of the different frameworks used to model disability in the social sciences, and how some of these frameworks could be used to boost creativity in the design of assistive devices. It then showcases a series of examples where innovative design ideas allowed for devices that go beyond trying to fix disability and instead liberate their users. The article concludes with a reflection on the ethical interactions between transhumanism and disability, as well as the possibilities created by new distributed design/construction networks affiliated with open-source/open-design models. This reflection can serve as a basis for a discussion about the necessary evolution of industrial practices in the design of assistive technologies, no matter whether they are designed to compensate impairments or augment capabilities.
**Key words**: User ; centred design ; Prosthesis ; Assistive technologies ; Disability studies ; Transhumanism ; Crip theory

# Technical Session B2

*18th November 2021, 11h00-12h20*

*Bernon & Channel MS Teams 2*

# Reconfigurable Manufacturing Systems

*Chair: Yves Sallez*

**An approach to jointly optimize the process plan, scheduling, and layout design in reconfigurable manufacturing systems.**

*Isabel Barros Garcia, Joanna Daaboul, Antoine Jouglet, Julien Le Duigou*

**Contribution of the Omni-directional Autonomous Mobile Robot to Manufacturing Systems Agility**

*Jeannette Flayfel, Guillaume Demesure, Hind Bril El Haouzi*

**Machine Learning and Autonomous Control - A Synergy for Manufacturing.**

*Oliver Antons, Julia C. Arlinghaus*

**SmartLab: a concept of Reconfigurable Assembly System designed in INSA Hauts-de-France.**

*Thierry Berger, Jean-Jacques Santin, Sondes Chaabane, Antoine Dequidt, Yves Sallez*

- ***18th November 2021, 11h00-12h20****. Technical Session B2 - Bernon (&Teams 2)*

***Reconfigurable Manufacturing Systems***

Chair: Yves Sallez

**Abstract**: To cope with several types of change, e.g., product variety due to mass customization, demand fluctuation, and production variability, manufacturing systems must continually adapt their production capacity and functionality. In the last decade, Reconfigurable Manufacturing Systems (RMS) have been proposed to deal with mass-customization problems and volatile markets. RMS are based on the modularization of production systems to increase their flexibility/agility, while improving their ramp-up time, their responsiveness, and their resilience to change. RMS make it possible, for example, to adapt the number and arrangement of resources (machines, robots, operators, internal transport logistics, etc.) according to variations in demand or the availability / reliability of equipment. These manufacturing systems can benefit from the new methodological and technological developments in the field of Industry 4.0. Thus, these new developments give birth to new forms of cooperation / collaboration between human operators and robots (cobotics), or between robots (stationary or mobile) and machines. If these new technologies are profitable to the RMS development, they induce equally new issues (e.g., need of new safety approaches for reconfiguration of robotized units, need of new human-resource-product interaction protocols and mechanisms, etc.).

**Key words**: Reconfigurable manufacturing system, scheduling, reconfiguration, safety, control, layout, Cyber physical Systems

11h - B21 - **An approach to jointly optimize the process plan, scheduling, and layout design in reconfigurable manufacturing systems**

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**Abstract**: Reconfigurable manufacturing systems (RMS) are a new paradigm studied to respond to current industry challenges like customized products, demand variation, and a shorter product life cycle. One of the main challenges in RMS is their optimization, which can be related to different issues: process planning, scheduling, layout design, line balancing, reconfigurability, product family design, etc. Although RMS optimization is gaining interest from academics and industries, RMS layout optimization is still understudied, especially when integrated with others. This work proposes a model formulation to jointly optimize the process planning, scheduling, and layout in the RMS context. The proposed mathematical model was validated with a numerical example solved using a commercial solver.

**Key words**: Reconfigurable Manufacturing Systems ; Scheduling ; Process Planning ; Layout.

11h20 – B22 - **Contribution of the Omni-directional Autonomous Mobile Robot to Manufacturing Systems Agility**

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**Abstract**: Nowadays, achieving a certain level of agility in a manufacturing system represents a step forward in the direction of Industry 4.0. As material handling is a very important aspect of production systems, the use of Autonomous Mobile Robots has started to gain increasing popularity in the manufacturing domain. This paper focuses on two main problems. The first one is the study apropos achieving the agility needed for a continuous changing demand in a shopfloor with focus on the best material handling solutions which are considered as the Autonomous Mobile Robots. The second problem addressed in this paper is the actual implementation of the robot with the help of a Particle Swarm Optimization algorithm for the robot path planning and Matlab (Simulink) for the robot control and path tracking.
**Key words**: Manufacturing agility ; Autonomous mobile robots ; Automated Guided Vehicles.

11h40 – B23 - **Machine Learning and Autonomous Control - A Synergy for Manufacturing**

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**Abstract**: This papers studies the synergistic potentials of machine learning and distributed control approaches in a job-shop setting. We utilize a multi-agent based discrete-event simulation to model distributed control in conjunction with a neural network to predict the optimal workshop configuration given fluctuating production demands. Within this simulation model, we study the potential cost and time savings, showing various potentials in the synergistic utilization of distributed control and machine learning for production planning and control in a job-shop manufacturing network.
**Key words**: Multi ; Agent System ; Discrete ; event Simulation ; Distributed Control ; Autonomous Control ; Neural Networks

12h – B24 - **SmartLab: a concept of Reconfigurable Assembly System designed in INSA Hauts-de-France**

Thierry Berger[1], Jean-Jacques Santin[1], Sondes Chaabane[1], Antoine Dequidt[1], Yves Sallez[1]
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**Abstract**: After setting the context of Reconfigurable Manufacturing System, an experimental platform developed at INSA Hauts-de-France called "SmartLab" is described. The SmartLab is a Reconfigurable Assembly System used for research and education purposes. This paper is more focused on the latter aspect: the SmartLab is used by students in their final year of engineering school at INSA Haut-de-France to discover and deal with many concepts related to the factory of the future. The basic design principles, the material, informational and safety aspects are successively described. Finally, the emphasis is on an educational use of the SmartLab during a final year student project
**Key words**: reconfigurable manufacturing system ; reconfigurable assembly system ; real experimental platform ; factory of the future

# Technical Session C

*18th November 2021, 15h00-16h00*

*Amphitheater & Channel MS Teams 1*

# Multi-agent and holonic approaches in smart manufacturing PART 1

*Chair Hind Bril El Haouzi*

## Aggregation Patterns in Holonic Manufacturing Systems

*Pascal Andre, Olivier Cardin*

## Fault-Tolerance in Cyber-Physical Systems using Holonic Multi-agent Systems

*D Luis Piardi, Paulo Leitão, Pedro Costa, André Schneider De Oliveira*

## Multi-agent System Specification for Distributed Scheduling in Home Health Care

*Filipe Alves, Ana Rocha, Ana Pereira, Paulo Leitão*

- ***18th November 2021, 15h00-16h00.*** *Technical Session C - Amphitheater (&Teams 1)*
  ***Multi-agent and holonic approaches in smart manufacturing PART 1***
  Chair: Theodor Borangiu

**Abstract**: Competitive production enterprises must be cost efficient, robust to resource failures and unexpected events, and agile to rapid changes in product type and demand. Centralized control systems lack the operational flexibility to adapt as close as possible to such changes in real time. The solution consists in decentralizing the control and distributing intelligence among shop floor devices, while preserving optimized, reality-aware supervision at global production horizon.

The distribution of intelligence in the industrial control system, and the need for collaborative decisions of strongly coupled plant entities led to the adoption of a new modelling approach for robust and optimized process control with agent-based implementing frameworks and holonic organization. This approach is based on the virtualization of a set of abstract entities: products (reflecting the client's needs), resources (reflecting the producer's capabilities, skills) and orders (reflecting business solutions) modelled by autonomous holons collaborating in holarchies by means of their information counterparts - intelligent agents that are organized in dynamic clusters to reach a common, production-related goal.

Decentralized, semi-heterarchical control and distribution of intelligence are implemented in multi-agent frameworks that build up 'smart' manufacturing control systems. This type of control architecture is distributed in agent clusters at the edge of the shop floor for big data collecting, and then centralized at cloud computing layer platform for aggregation, machine learning and intelligent decision making: predictive production planning, real time batch optimization, dynamic resource reconfiguring, detecting anomalies and unexpected events.

The concept of Internet of Things (IoT) takes advantage of the new communication and decision mechanisms, and thus it can provide solutions both for industrial areas - Industrial IoT and also for many other application fields. The integration with IoT of intelligent techniques like holonic and multi-agent systems has a great potential, while it determines new challenges for research.

**Key words**: Multi-agent systems, holonic manufacturing organization, intelligence distribution, shop floor instrumenting, edge and fog computing, semi-heterachical control, product-driven automation, smart manufacturing control system, Internet of Things

15h - C1 - **Aggregation Patterns in Holonic Manufacturing Systems**

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**Abstract**: Holonic Manufacturing Systems (HMS) constitute an application of multi-agent systems for the control of manufacturing systems. In comparison with other multi-agent based architectures, holarchies exhibit aggregation features. As a matter of fact, all the holonic reference architectures possess aggregation-based relations, and these features are even usually described as mandatory. However, practitioners trying to implement holonic control architectures are all facing the same issue: this specificity implies many software engineering difficulties. Indeed, the models are generally not specified enough and lead the developers to make a lot of hypotheses, which are the origin of inconsistencies, misbehaviours or code maintenance issues. This article is based on the most common architecture: PROSA. The objective is to illustrate the lack of specification of the model, and introduce several ways to cope with them: better specifying the classes, better specifying the relations and finally introducing some coherent development methods.

**Key words**: Holonic Manufacturing Systems ; PROSA ; Aggregation ; Modelling ; Design pattern ; Software engineering

15h20 – C2 - **Fault-Tolerance in Cyber-Physical Systems using Holonic Multi-agent Systems**

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**Abstract**: Cyber-Physical Systems (CPS) transforms traditional systems into a network of connected and heterogeneous systems, integrating computational and physical elements, which works as a complex system whose overall properties are greater than the sum of its parts. However, CPS is not free from faulty episodes and their consequences, such as malfunctions, breakdowns, and service interruption. Traditional centralized models for fault-tolerance do not meet the complexity of the current industrial scenarios and particularly the industrial CPS requirements. Having this in mind, this work presents a holonic-based architecture to address the fault-tolerance in CPS that distributes the detection, diagnosis, and recovery by the local individual entities but also considers the emergent behavior resulting from the collaboration of these individuals. An experimental case study was used to illustrate the potential application of the fault-tolerant approach.

**Key words**: Fault Tolerance ; Cyber Physical Systems ; Holonic Multi agent Systems

15h40 – C3 - **Multi-agent System Specification for Distributed Scheduling in Home Health Care**

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**Abstract**: Nowadays, scheduling and allocation of resources and tasks becomes a huge and complex challenge to the most diverse industrial areas, markets, services and health. The problem with current scheduling systems is that their management still occurs manually or using classical optimization methods, usually static, time-consuming and centralized approaches. However, opportunities arise to decentralize solutions with smart systems, which enable the distribution of the computational effort, the flexibility of behaviors and the minimization of operating times and operational planning costs. The paper proposes the specification of a Multi-agent System (MAS) for the Home Health Care (HHC) scheduling and allocation. The MAS technology enables the scheduling of intelligent behaviors and functionalities based on the interaction of agents and allows an evolution of current strategies and algorithms, as it can guarantee the fast response to condition changes, flexibility and responsiveness in existing planning systems. An experimental HHC case study was considered to test the feasibility and effectiveness of the proposed MAS approach, with the results demonstrating promising qualitative and quantitative indicators regarding the efficiency and responsiveness of the HHC scheduling

**Key words**: Multiagent System ; Home Health Care ; Distributed Scheduling

# Technical Session D1

*18th November 2021, 16h20-18h20*

*Amphitheater & Channel MS Teams 1*

# Digital Twins in Cyber-Physical Industrial Systems

*Chair: Olivier Cardin*

**About perfection of digital twin models.**

*Farah Abdoune, Olivier Cardin, Maroua Nouiri, Pierre Castagna*

**Digital Twin for production systems: a literature perspective**

*Ksenia Pystina, Aicha Sekhari Seklouli, Lilia Gzara, Vincent Cheutet*

**Digital Twins for Distributed Intellingent Sensing and Control Systems.**

*Jonathan Lesage, Robert Brennan*

**Towards the Integration of Digital Twins and Service-Oriented Architectures.**

*Karel Kruger, Carlo Human, Anton Basson*

**Trust Model for Digital Twin based Recommendation System.**

*Flávia Pires, Paulo Leitão, António Paulo Moreira*

**TYPOLOGY OF MANUFACTURING DIGITAL TWINS: A FIRST STEP TOWARDS A DEPLOYMENT METHODOLOGY.**

*Nathalie Julien, Eric Martin*

- ***18th November 2021, 16h20-18h20**. Technical Session D1 - Amphitheater (&Teams 1)*
  ***Digital Twins in Cyber-Physical Industrial Systems***
  Chair: Olivier Cardin

**Abstract**: Cyber-Physical Industrial Systems are considered in many ways as a structuring paradigm of future industrial systems. The physical layer generally contains the assets, the operators, the real-time control system and the production managers. The cyber layer is in charge of extracting data and knowledge from the behaviour of the physical layer to analyse it with respect to the current environment and objectives of the system, and potentially trigger a reconfiguration of the physical layer. In this cyber layer, the need for a virtual replica of the actual behaviour of the physical system is crucial to gather the information needed for the analysis. This replica, sort of cyber model of the system, is generally referred as the Digital Twin (DT) of the system.

This DT is meant to be the first element of the loop enabling efficient development of knowledge extraction and analysis, and therefore requires a high effort of modelling and implementation. The notion of the Digital Twin in itself, as being to reflect not only the data but also the behaviour of the physical layer, is still not clearly defined and very few proofs of concept can be found. However, several projects in different fields of application involve academia and/or industry all around the world. It becomes now crucial to foster the emergence of a global picture of the Digital Twin that could be accepted by the largest community and show the benefits of the application of such a tool in operations.

This session aims at bringing together multiple actors of this concept in order to foster convergence, innovative tools and applications. All the aspects of the implementation of a Digital Twin in cyber-physical industrial systems are targeted. Position papers and applications feedback are particularly welcome. Works on the generic architecture of a Twin are of great interest, as well as applications and proofs of concepts in industry or learning factories.

**Key words**: Digital Twin, Digital Shadow, Digital Model, cyber-physical industrial systems

16h20 - D11 - **About perfection of digital twin models**

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**Abstract**: Modeling and real-time control methods continue to face major challenges like the lack of models capable of accurately replicating the physical systems while integrating real-time manufacturing data. In this context, the digital twin has widely emerged to address this challenge to connect the physical and digital worlds. The interdependent combination of digital model and physical assets must be harmonized with one another to work efficiently. For this reason, the virtual model needs to be thoroughly evaluated and validated before implementing it in the general framework. In this paper, we discuss the different modelling methods of the virtual model and the various approaches to validate it used in literature.

**Key words**: digital twin ; machine learning ; model generation ; virtual model

16h40 – D12 - **Digital Twin for production systems: a literature perspective**

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**Abstract**: Digital Twin is one of the key enabling technologies of the fourth industrial evolution. Alongside with the cyber-physical systems, it is expected to widen the perspectives of smart manufacturing development and for production systems in particular. For these systems on-going state monitoring, simulation and prediction of manufacturing operations are crucial

to improve the production efficiency and flexibility. Moreover, through the principles of system engineering, Digital Twin establishes interconnection and interoperability between cyber and physical environments, allowing a human to act confidently based on accurately analysed data and verified simulation models. In order to design and implement Digital Twin the architecture and main components must be identified.

**Key words**: Digital Twin ; architecture ; cyber ; physical systems ; smart manufacturing ; production systems

17h – D13 - **Digital Twins for Distributed Intellingent Sensing and Control Systems**

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**Abstract**: Digital twins present revolutionary potential in smart manufacturing and production. However, their current application in distributed control systems is minimal and largely unexplored. By applying digital twins to distributed control systems, distributed intelligent sensing and control systems may be achieved. These systems are fully automated and self-managing, making them a valuable asset.

In this paper, we provide a short literature review which establishes the definition, application, and implementation of digital twins in smart manufacturing and production. Based on this review, we propose their application in transforming distributed control systems into distributed intelligent and sensing control systems. We identify features of a digital twin which will be of greatest use in a distributed control system, and discuss our current research direction aimed at interfacing these control systems with digital twins.

**Key words**: Digital Twin ; Cyber Physical Production System ; Distributed Control System ; Distributed Intelligent Sensing and Control System ; IEC 61499

17h20 – D14 - **Towards the Integration of Digital Twins and Service-Oriented Architectures**

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**Abstract**: Digital twins and service-orientated architectures have developed in different research communities, but share some similar target uses. This paper proposes a general architecture that couples aggregations of digital twins with a services network to create digital decision support systems for complex cyber-physical systems. The proposed architecture is intended for complex cyber-physical systems, provides for multiple stakeholders to contribute to the development and operation of the system and provides the ability for the digital system to evolve over time as the physical system evolves and to allow the functionality of the digital system to be adapted as information needs and resources change over time. The architecture is expected to be applicable to manufacturing scenarios ranging from SMEs to larger enterprises, but also to areas such as management of complex facilities (such as a university campus), water distribution systems and railway infrastructure. Some challenges associated with the proposed architecture, related to the integration of digital twin and service-oriented architectures, are outlined

**Key words**: Digital Twin ; Service ; orientated ; Complex ; Cyber ; Physical Systems

17h40 – D15 - **Trust Model for Digital Twin based Recommendation System**

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**Abstract**: The digital twin has been gaining significant attention from the academia and industry sectors in the last few years. The digital twin concept enables monitoring, diagnosis, optimisation, and decision support tasks to improve industrial systems operation. One of the identified challenges in this field is the need to improve the decision support cycle by decreasing decision-making time and improving the accuracy of recommendations by considering human intervention in the cycle. Bearing this in mind, this paper explores the use of trust models to improve the recommendation cycle in the digital twin. For this purpose, a literature overview on trust applied in recommendation systems was performed, focusing on the concept, its properties and previous models. Considering this analysis, a trust-based model is specified in a digital twin artificial intelligence-based recommendation system

**Key words**: Digital Twin ; Trust Models ; Recommendation Systems

18h – D16 - **TYPOLOGY OF MANUFACTURING DIGITAL TWINS: A FIRST STEP TOWARDS A DEPLOYMENT METHODOLOGY**

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**Abstract**: The digital twin is not only a recent technology but also a polymorphic concept which generates a profusion of publications without real coherence because they relate to very different realities including various definitions, shapes, models and applications. If a wide variety of architectures are proposed, there is a significant lack of information on how to deploy a digital twin efficiently and how to define an appropriate architecture. We propose the first step of a complete deployment methodology consisting of a typology that defines the main criteria required to determine not only the digital twin components but also their organization. Based on different recent works that have been synthesized and completed, eleven criteria have been selected as representative of the set of usages and applications proposed in the literature. They will then allow us to propose a generic architecture that best meets the targeted application

**Key words**: Digital Twin ; Agile Manufacturing ; Generic Architecture ; Deployment Methodology ; Smart Manufacturing Systems

# Technical Session D2

*18th November 2021, 16h20-18h20*

*Bernon & Channel MS Teams 2*

# Efficient and intelligent monitoring and control of industrial systems

*Chair: William Derigent*

**An evaluation of pick on the fly methods for high-speed part processing in low cost digital manufacturing.**

*Florin Anton , Theodor Borangiu, Silvia Anton, Silviu Raileanu , Andrei Lisita*

**Health Indices Construction for Stochastically Deteriorating Feedback Control Systems**

*Yufei Gong, Khac Tuan Huynh, Yves Langeron, Antoine Grall*

**Model-based Engineering for Designing Cyber-Physical Systems Control Architecture and Improving Adaptability from Requirements**

*Alexandre Parant, François Gellot, Alexandre Philippot, Véronique Carre-Menetrier*

**Real-time Image Analysis with Neural Networks on Industrial Controllers for Individualized Production.**

*Christoph Wree, Rando Raßmann, Janis Daas, Fabian Bause, Tobias Schönfeld*

**Robotic Process Automation for Efficient Enterprise Business Management.**

*Radu Florin Negoita, Theodor Borangiu, Iulia Iacob, Maximilian Nicolae*

**Predicting instances demand and occupancy toward efficient VMs rightsizing and resources allocation strategies: Amazon case study.**

*Ikhlasse Hamzaoui, Benjamin Duthil, Vincent Courboulay, Hicham Medromi*

- ***18th November 2021, 16h20-18h20**. Technical Session D2 - Bernon (&Teams 2)*
  ***Efficient and intelligent monitoring and control of industrial systems***
  Chair: William Derigent

16h20 - D21 - **An evaluation of pick on the fly methods for high-speed part processing in low cost digital manufacturing**

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**Abstract**: A solution that increases productivity and reduces cycle time in robotised manufacturing applications consists in implementing interactions with moving components of material flows using pick on the fly techniques. Picking parts "on the fly" or "while in motion" allows streams of parts transported by conveyors to be processed by one or more robot stations without stopping the belt or the part on the belt. In many cases the parts are recognized by a camera which sends the position and orientation of the object to the robot (this is done because in many situations the part is not fixed on a pallet so it may be placed on the conveyor with different positions and orientations) and then, the robot tracks the object on the conveyor using the information provided by an encoder mounted on the belt. The paper presents an evaluation of three different methods for implementing pick on the fly applications: using only a camera, using a camera and a standard belt encoder, and using a camera and a "no touch" laser-based encoder.

**Key words**: Robotised manufacturing ; pick on the fly application ; belt tracking ; machine vision ; "no touch" encoder

16h40 – D22 - **Health Indices Construction for Stochastically Deteriorating Feedback Control Systems**

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**Abstract**: Health index is a key input for the predictive maintenance or control reconfiguration of systems. This paper deals with the degradation and failure of a feedback control system using proportional-integral-derivative controller. Actually, the controller allows the system fault tolerance to fulfill certain required missions, but also hides the effect of damages inherent in the feedback control system, and hence renders more difficulty in the system health monitoring. Faced with this problem, we propose in this paper an efficient approach to specify indices of the system degradation and failure. The originality resides mainly in the assumption that the system input-output are the only monitoring information available for the feedback control system, and that no knowledge about the system physics is required. The monitoring data are first employed to construct the transfer function of the system. On the basis of this model, we next build two degradation indices for the system: (i) one based on the system poles, and (ii) another based on the maximum gain of the transfer function. Associated with each degradation index, a threshold is proposed to define the system failure. For an illustration, we apply the proposed approach to a stochastically deteriorating stabilization loop control device in an inertial platform to assess its health state

**Key words**: feedback control systems ; stochastic degradation ; random failure ; condition monitoring ; health index

17h – D23 - **Model-based Engineering for Designing Cyber-Physical Systems Control Architecture and Improving Adaptability from Requirements**

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**Abstract**: Model-Based Engineering (MBE) is a method for reducing complexity in system design. This paper presents a methodology for designing Cyber-Physical System (CPS) and its control system using System Modelling Language (SysML) diagrams and IEC 61499 standard. The real-time control system is designed from high-level knowledge and tested software components on the plug and produce principle. This paper presents an application case to demonstrate the feasibility of our approach. In addition, a set of solutions is presented to reduce the time and improve the engineering and traceability of configuration changes during the system lifecycle.

**Key words**: Cyber Physical System ; Model Based Engineering ; System Modeling Language ; IEC 61499 ; Reconfiguration

17h20 – D24 - **Real-time Image Analysis with Neural Networks on Industrial Controllers for Individualized Production**

Christoph Wree[1], Rando Raßmann[1], Janis Daas[1], Fabian Bause[2], Tobias Schönfeld[2]
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**Abstract**: Manufacturing systems for individualized production require workflows depending on individual objects. Machine learning (ML) offers the possibility to classify different objects by training a neural network. Depending on the output values of the network, decisions for the following production step can then be controlled. The question arises whether it is possible to execute the neural network in real time in coordination with the machine and motion control tasks. In this paper, this question is investigated using a programmable logic controller (PLC) runtime environment on a standard industrial PC. The execution times of different neural network implementation methods are measured and compared. The fastest neural network requires an average execution time of only 54 µs. The characteristics of the different methods with respect to training and implementing the neural networks in the controller are also discussed

**Key words**: Machine Learning ; Intelligent Manufacturing Systems ; Individualized Production

17h40 – D25 - **Robotic Process Automation for Efficient Enterprise Business Management**

Radu Florin Negoita, Theodor Borangiu, Iulia Iacob, Maximilian Nicolae
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**Abstract**: Nowadays, enterprise processes are gradually subject to digital transformation, significantly reducing the intervention of the human agent. The automation is going to spread both on technical and business processes of the enterprise. A very important technology for the automation of high volume, repetitive, mainly routine business processes is represented by Robotic Process Automation (RPA) which consists in creating a process that simulates the activity of a human agent and replicating it, by delegating a software robot to do it. The area of RPA usability is very vast like accounting, inventory, finance, human resources, and extends to composite Supply Chain Management (SCM) and Customer Relationship Management (CRM) processes as part of Enterprise Business Management. The paper describes an RPA solution for a company that provides repair and maintenance services for technology resources (busses, trucks) of public and private transport organizations, and that can be easily adopted in other fields of activity that involve SCM and CRM. The necessary steps to set up an RPA robot that simplifies enterprise business logistics activities and brings value to the business are presented. First, RPA functionalities are stated; next, the role of RPA in Enterprise Business Management is described; a particular RPA solution is developed for the enterprise's taxation and invoicing process. Experimental results obtained by running the automated processes are finally reported.

**Key words**: Robotic Process Automation, Enterprise business logistics, Service orientation, Automatic taxation and invoicing

18h – D26 - **Predicting instances demand and occupancy toward efficient VMs rightsizing and resources allocation strategies: Amazon case study**

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**Abstract**: As cloud traffic never stop growing in minutes, hours and daily basis, proactive cloud resources orchestration become a prerequisite. In this paper, we investigate an Amazon case study, in which we intent to compare respectively univariate and multivariate predictions of multimodal AWS instances demand and their related instances resources occupancies. For this purpose, we implemented four nonlinear deep neural network models, namely: LSTM, GRU with their bidirectional variants BiLSTM and BiGRU. Experimentation test scenarios demonstrated the performance of

BiGRU models above other candidate models, achieving until (0.71, 0.11, 0.26, 0.97) of RMSE values, respectively while predicting four instances families' future demands. Adopting an extended BiGRU version, we further demonstrate how multivariate predictions remain much less accurate than univariate forecasting scenarios

**Key words**: cloud computing ; instances demand ; instances occupations ; deep neural networks (DNNs) ; univariate and multivariate time series prediction.

# Technical Session E

*19th November 2021, 9h40-10h40*

*Amphitheater & Channel MS Teams 1*

# Multi-agent and holonic approaches in smart manufacturing PART 2

*Chair: Theodor Borangiu*

**Applying learning-assisted systems in manufacturing**

*Carlos Pascal, Doru Panescu*

**Generalising service interactions in the BASE architecture for holonic manufacturing systems**

*Daniel Van Niekerk, Karel Kruger, Anton Basson*

**Virtualizing Product-on-Pallet Distribution Systems in Logistics 4.0 Vision**

*Mihai Stan, Theodor Borangiu, Silviu Raileanu*

- ***19th November 2021, 9h40-10h40.*** *Technical Session E - Amphitheater (&Teams 1)*
  ***Multi-agent and holonic approaches in smart manufacturing PART 2***
  Chair: Theodor Borangiu

9h40 - E1 - **Applying learning-assisted systems in manufacturing**

Carlos Pascal, Doru Panescu
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**Abstract**: The paper addresses a topical subject, namely a possibility of combining some frequent components of Industry 4.0. There are used an adapted IoT communication, machine learning and computer vision-based robotics in order to obtain a better performance for manufacturing control. There are envisaged a faster operation for a vision guided robotic application, an increased adaptability, and the overcoming of some difficult points that appear when machine learning is used in an industrial application (getting a proper dataset, a quick training mechanism). It is proposed an assisted manufacturing control architecture that was inspired by the Assisted Global Positioning System (A-GPS). Thus, the performance of a manufacturing control scheme can be improved if an assister (an additional component, in our case a second computer vision system) is used together with a properly devised communication protocol. The paper gives the details of a learning-assisted system, which means that a machine learning component is involved. The application that was solved with promising results is about part identification, inspection, and robot manipulation. The obtained conclusion underlines the efficiency of the proposed solution when certain elements of IoT and artificial intelligence are combined.

**Key words**: manufacturing systems ; IoT ; machine learning ; assisted systems

10h00 – E2 - **Generalising service interactions in the BASE architecture for holonic manufacturing systems**

Daniel Van Niekerk, Karel Kruger, Anton Basson
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**Abstract**: The Holonic Manufacturing Systems paradigm can greatly assist the development of Cyber-Physical Systems. This paper describes the use of the Biography-Attributes-Schedule-Execution (BASE) architecture – a holonic digital administration shell architecture, originally developed for human integration – for the implementation of Service-oriented Holonic Manufacturing Systems (SoHMSs). An overview of the BASE architecture, and its application in SoHMSs, is presented to provide the necessary context. The paper then describes how holon services are structured within the BASE architecture and how holons can provide and/or request services from each other using generalised service provision plugins.

**Key words**: Cyber Physical Systems ; Holonic Manufacturing Systems ; Service oriented architecture ; Service oriented Holonic Manufacturing Systems

10h20 – E3 - **Virtualizing Product-on-Pallet Distribution Systems in Logistics 4.0 Vision**

Mihai Stan, Theodor Borangiu, Silviu Raileanu
Dept. of Automation and Applied Informatics, University Politehnica of Bucharest, Romania
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**Abstract**: The paper describes the design of a mixed order planning and activity scheduling system for the production of goods integrated with the logistics for their distribution on pallets. The supervision strategy is developed in the holonic control paradigm which is used to define a 2-layer Logistics Execution System (HLES) for the main logistics stage - palletizing product packages. Global HLES workloads consist in order planning and scheduling for product distribution on weekly and daily basis and execute on the higher level - the System Scheduler. An implementation of the global workload optimization is presented: it uses Constraint Programming as decision making technology with ILOG optimizer engine as situation-specific solver tool. The objective function is a combination of palletizing cost weighted by robot speed limits and storage costs in payable stocks.

**Key words**: Logistics 4.0 ; Logistics Execution System ; holonic control ; System Scheduler ; decentralized palletizing ; PLC ; robot handshake

# Technical Session F1

*19th November 2021, 11h00-13h00*

*Amphitheater & Channel MS Teams 1*

## Digital manufacturing

*Chair: Silviu Raileanu*

### A Graphical Environment to Support the Development of Affordable Digital Manufacturing Solutions.

*Zhengyang Ling, Lavindra De Silva, Gregory Hawkridge, Duncan Mcfarlane, Giovanna Martinez Arellano, Benjamin Schönfuß, Alan Thorne*

### Designing Shoestring Solutions: An approach for designing low-cost digital solutions for manufacturing

*Gregory Hawkridge, Duncan Mcfarlane, Jan Kaiser, Lavindra De Silva, German Terrazas*

### Maturity Evaluation for Workforce Management - an integrated approach to assess digital maturity of workforce management systems.

*Sebastian Häberer, Julia Arlinghaus*

### Review and Classification of Digital Manufacturing Reference Architectures.

*Jan Kaiser, Duncan Mcfarlane, Gregory Hawkridge*

### SI4M: An approach of maturity assessment model on industry 4.0 for small and medium enterprises.

*Jose-Fernando Jimenez, Harry-Andres Avila, Jorge-Alberto Gomez, Alexander Cardenas-Ramos*

### Visualisation on a Shoestring: a low cost approach for building visualisation components of industrial digital solutions.

*Giovanna Martinez Arellano, Michael J. Mcnally, Jack C. Chaplin, Zhengyang Ling, Duncan Mcfarlane, Svetan Ratchev*

- ***19th November 2021, 11h00-13h00****. Technical Session F1 - Amphitheater (&Teams 1)*
  ***Digital manufacturing***
  Chair: Silviu Raileanu

11h00 - F11 - **A Graphical Environment to Support the Development of Affordable Digital Manufacturing Solutions**

Zhengyang Ling[1], Lavindra De Silva[1], Gregory Hawkridge[1], Duncan Mcfarlane[1], Giovanna Martinez Arellano[2], Benjamin Schönfuß[1], Alan Thorne[1]
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Cambridge, UK - United Kingdom
2 : University of Nottingham
Nottingham - United Kingdom

**Abstract**: Digital solutions have the potential to drastically transform manufacturing operations, but smaller manufacturing businesses (SMEs) have been reluctant to adopt digital solutions due to perceived investment and upskilling costs. The Digital Manufacturing on a Shoestring project was thus established to facilitate the process of digital solution adoption in manufacturing SMEs. To this end, a solution development approach was proposed including a graphical environment to support the design of affordable digital solutions. This paper discusses the concepts and methods underlying this graphical design environment, including its early implementation. A preliminary evaluation is also presented involving industrial user studies with SMEs.
**Key words**: Digital Manufacturing ; Low Cost ; Graphical Support Environment

11h20 – F12 - **Designing Shoestring Solutions: An approach for designing low-cost digital solutions for manufacturing**

Gregory Hawkridge, Duncan Mcfarlane, Jan Kaiser, Lavindra De Silva, German Terrazas
Institute for Manufacturing
Cambridge University Engineering Department, 17 Charles Babbage Road, Cambridge, CB3 0FS, UK - United Kingdom

**Abstract**: This paper examines the design of low-cost digital solutions for manufacturing. A set of criteria are established that take into account the limited designer experience and limited time budget that accompany a low-cost project. Alternatives are assessed and a design approach is proposed that addresses these criteria using a set of identified features. Development of the proposed approach is not yet complete, however it already provides a simple, accessible, and streamlined method for implementing low-cost digital solutions
**Key words**: Low Cost ; Digital Manufacturing ; System Design

11h40 – F13 - **Maturity Evaluation for Workforce Management - an integrated approach to assess digital maturity of workforce management systems**

Sebastian Häberer[1], Julia Arlinghaus[2]
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**Abstract**: Flexible workforce allocation has become a crucial factor for the success of a company and the satisfaction of its employees. The degree of digitization in the core process of workforce allocation as well as the upstream and down-stream processes play a decisive role for planning efforts, error-proneness and employee satisfaction in an integrated workforce management concept. However, the integrated evaluation of human, technology and organization in a holistic workforce management is currently hardly achievable with ex-isting methods due to the complexity of the topic. In this research, we de-velop a scientifically based maturity model for the holistic and process-oriented evaluation of such workforce management concepts. Therefore, we derive implications for research and practice
**Key words**: workforce management ; integrated evaluation ; maturity model ; shop floor ; human ; technology ; organization

12h – F14 - **Review and Classification of Digital Manufacturing Reference Architectures**

Jan Kaiser, Duncan Mcfarlane, Gregory Hawkridge
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**Abstract**: For the next generation of production systems, companies require new architectures for designing highly connected systems to increase the efficiency and capabilities of their value chains. Reference architectures help to effectively derive systems architectures. Over the last decades, numerous reference architectures for digital manufacturing have been proposed. This paper presents a framework to classify reference architectures based on five main themes identified in the literature. It will identify gaps in existing reference architectures based on an analysis of the proposed framework and comparison to other classification approaches.

**Key words**: Industry 4.0 ; Reference Architecture ; Digital Manufacturing ; Internet of Things (IoT) ; Cyber ; Physical Systems (CPS)

12h20 – F15 - **SI4M: An approach of maturity assessment model on industry 4.0 for small and medium enterprises**

Jose-Fernando Jimenez[1], Harry-Andres Avila[2], Jorge-Alberto Gomez[2], Alexander Cardenas-Ramos[2]
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**Abstract**: Nowadays, small and medium businesses in the manufacturing industry face various challenges towards the deployment of the industry 4.0 revolution. Indeed, these enterprises need to come along with the new industrial development rapidly considering the deployment of the technology that supports the production and logistics operations. The new technological developments may be implemented easily in large enterprises due to several advantages, such as financial availability, proven technological deployment experiences and highly skilled workers. Nonetheless, these require tackling additional challenges for small and medium enterprises on the manufacturing industry, such as limited financial resources to upgrade their industrial processes. Aiming to contribute to industry 4.0 development, this paper proposes a new methodology that assess the maturity of small and medium enterprises in the manufacturing industry. This preliminary model, which is constructed considering the low-cost automation concept, and the requirements of small and medium enterprises, proposes a three phases evaluation, including a self-assessment phase, an expert-reinforcement categorisation phase and a roadmap improving phase. An earlier validation of the model is deployed for a bakery enterprise focusing on the functionality and usability of the methodological approach

**Key words**: Industry 4.0 ; technological maturity model ; small and medium enterprises ; manufacturing ; low ; cost automation

12h40 – F16 - **Visualisation on a Shoestring: a low cost approach for building visualisation components of industrial digital solutions**

Giovanna Martinez Arellano[1], Michael J. Mcnally[1], Jack C. Chaplin[1], Zhengyang Ling[2], Duncan Mcfarlane[2], Svetan Ratchev[1]
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**Abstract**: Current adoption of digital solutions in manufacturing environments remains low despite the benefits these can bring to manufacturing processes. This is particularly acute among industrial SMEs, who typically do not have the confidence to adopt new technologies and for which cost and lack of skills remain key barriers. Most digital solutions require some type of visualisation component, being a vital way to the interpret and use effectively the solution. Data visualisation on its own provides a good opportunity to bridge the gap of digitalisation in SMEs by providing them invaluable process insights in an efficient manner without requiring high levels of training or expertise. However, as with other digital technologies, software components such as data analytics and visualisation are commonly developed, deployed and maintained by a third party, and SMEs lack of the expertise to understand how to implement visualisations and how they can be applied in the manufacturing domain. The

Digital Manufacturing on a Shoestring approach proposes using off-the-shelf components, both hardware and software, to develop and deploy low-cost digital solutions with minimal expert knowledge. The underlying shoestring architecture enables the incremental connectivity of different solution components using a service-oriented approach. This paper introduces the implementation of visualisation as a service, where the main visual component of a digital solution is dynamically created by a set of reusable, configurable and modular elements. We also introduce the use of templates for the no-code creation of visual solutions, taking advantage of the re-usability of visual components across different digital solutions

**Key words**: digital manufacturing ; data visualisation ; service oriented architectures ; low cost digital manufacturing

# Technical Session F2

*19th November 2021, 11h-12h40*

*Bernon & Channel MS Teams 2*

# Intelligent control for a Sustainable and Efficient supply chain of the future

*Chair: Abdelghani Bekrar*

**An imitation learning approach for vehicles longitudinal obstacle avoidance in logistics and transportation.**

*Antoine Plissonneau, Damien Trentesaux, Abdelghani Bekrar, Wael Ben-Messaoud*

**Impact of Intelligent Product and BIM4D technologies on construction site monitoring: an experimentation framework**

*Haya Naanaa, Hind Bril El Haouzi, William Derigent*

**Multi-Agent Simulation for Flexible Job-Shop Scheduling ProblemWith Traffic-Aware Routing**

*Kader Sanogo, Abdelkader Mekhalef, M'hammed Sahnoun, Belgacem Bettayeb, Abdelghani Bekrar*

**Supply chain Application of Blockchain-based solutions for Cyber-Physical Systems: review and prospects.**

*Yassine Idel Mahjoub, Tarik Chargui, Abdelghani Bekrar, Damien Trentesaux*

**Toward efficient FMS scheduling through rules combination using an optimization-simulation mechanism.**

*Wassim Bouazza, Yves Sallez, Damien Trentesaux*

- ***19th November 2021, 11h-12h40****. Technical Session F2 - Amphitheater (&Teams 2)*
  ***Intelligent control for a Sustainable and Efficient supply chain of the future***
  Chair: Abdelghani Bekrar

**Abstract**: In the recent decades, sustainability became a very challenging problem for many domains, especially for logistic and transportation systems. Meanwhile, the industry and supply chain 4.0 are enhanced by new technologies (AGV, drones, IoT, …) that are becoming energy consuming and hardly designed to be environment-friendly. These technologies make also this new supply chain more complex. In addition, such a complexity can be increased by considering perturbations or unexcepted events (urgent order from customers, …). Moreover, sustainability imposes that an intelligent control continues to be efficient over the time (perturbations, etc.) and over the changing context (constraints and objectives).

The objective of this session is to present recent intelligent control approaches leading to efficient, robust and sustainable solutions for the supply chain of the future, whatever the addressed level (-operational, tactical and strategic level) and the addressed stage of the supply chain (procurement, production, customer delivery…). Such an intelligent control can be local and reactive (Multi-agent system, holonic approach,…) or global and static (Math model, metaheuristic, …)...

**Key words**: Intelligent control, sustainability, energy emission and consumption, Supply Chain Management, green supply chain, Physical Internet, Logistics.

11h - F21 - **An imitation learning approach for vehicles longitudinal obstacle avoidance in logistics and transportation**

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**Abstract**: Obstacle avoidance is a core module for autonomous vehicle working in open environment. A lot of research is concentrated to obstacle avoidance and path planning on vehicle moving in two or three dimensions. However, when it comes to one degree of freedom, the topic is still little explored. In this paper, an imitation learning approach for autonomous vehicles longitudinal obstacle avoidance is introduced. This work aims to show the interest of using a supervised learning approach to imitate human's behavior when driving in environments with unpredictable obstacles. Two machine learning methods, K-nearest neighbours and XGBoost, were integrated into our learning architecture and were tested on two applications in logistics and transportation. The results show the ability of our solution to cope with different types of vehicle dynamics. Our solution is for each application able to reproduce the same decision of an expert driver and to make a trip without collision and with acceptable time travel.

**Key words**: imitation learning ; autonomous vehicle ; obstacle avoidance ; logistics ; transportation

11h20 – F22 - **Impact of Intelligent Product and BIM4D technologies on construction site monitoring: an experimentation framework**

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**Abstract**: Industrialized building process has encouraged the utilization of new Information Technologies to boost the productivity and quality of construction projects. The use of the BIM (Building Information Modeling) technology combined with real time monitoring of the construction site could improve the planning throughout the building lifecycle. In the framework of the ANR McBIM Project, intelligent building products made of communicating concrete are currently being designed. These products, equipped with micro-electronic devices, can report their statuses in real-time. This paper thus investigates the use of such products combined with BIM technologies and explores the potential benefits in terms of cost for the management of construction sites, depending on their organization pattern

**Key words**: Building Information Modelling; Real time monitoring ; Building lifecycle ; Planning

11h40 – F23 - **Multi-Agent Simulation for Flexible Job-Shop Scheduling Problem With Traffic-Aware Routing**

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**Abstract**: This paper addresses the Flexible Job Shop Scheduling Problem (FJSSP) with transportation tasks between processing machines ensured by Automated Guided Vehicles (AGVs). It aims to study the effect of two operational constraints, usually neglected in literature, namely the traffic interactions between AGVs and loading/unloading operations. A multi-agent simulator is developed to simulate and analyse the system and to test some hypothesis. The proposed approach is tested on two scenarios: with and without collision avoidance assumption. Results have shown that collision avoidance assumption adds extra time to the Makespan. However, these results bring us closer to reality and highlight the need to take into account such interactions in the advanced planning/scheduling of production and transportation tasks in flexible manufacturing systems (FMS).

**Key words**: Dynamic scheduling ; AGV ; Multiagent simulation ; Flexible job shop scheduling problem ; Intelligent control

12h00 – F24 - **Supply chain Application of Blockchain-based solutions for Cyber-Physical Systems: review and prospects**

Yassine Idel Mahjoub, Tarik Chargui, Abdelghani Bekrar, Damien Trentesaux
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Laboratoire d'Automatique, de Mécanique et d'Informatique industrielles et Humaines, Université Polytechnique Hauts-de-France
Université Polytechnique Hauts-de-France, Le Mont Houy, 59313, Valenciennes, France.

**Abstract**: Cyber-Physical Systems (CPS) are a new generation of systems that involves engineered computing and communicating systems interfacing the physical world, often interacting with a highly uncertain and adverse environment, including humans and other CPS. Flawless integration of these systems still faces various challenges, e.g., interoperability, decentralization, trust, privacy, and security. Thanks to its salient features, Blockchain is a promising technology that could efficiently address these challenges. This paper provides insights and explores the opportunities and challenges of incorporating CPS and Blockchain technology. As a propitious industrial application, this paper highlights blockchain-based CPS solutions for Supply Chain Management (SCM). We present opportunities, established projects, and some use cases. Finally, we point out some open research issues and outline future research directions

**Key words**: Cyber ; Physical Systems ; Blockchain ; IoT ; Supply chain management ; Security ; Decentralization ; Smart contracts

12h20 – F25 - **Toward efficient FMS scheduling through rules combina-tion using an optimization-simulation mechanism**

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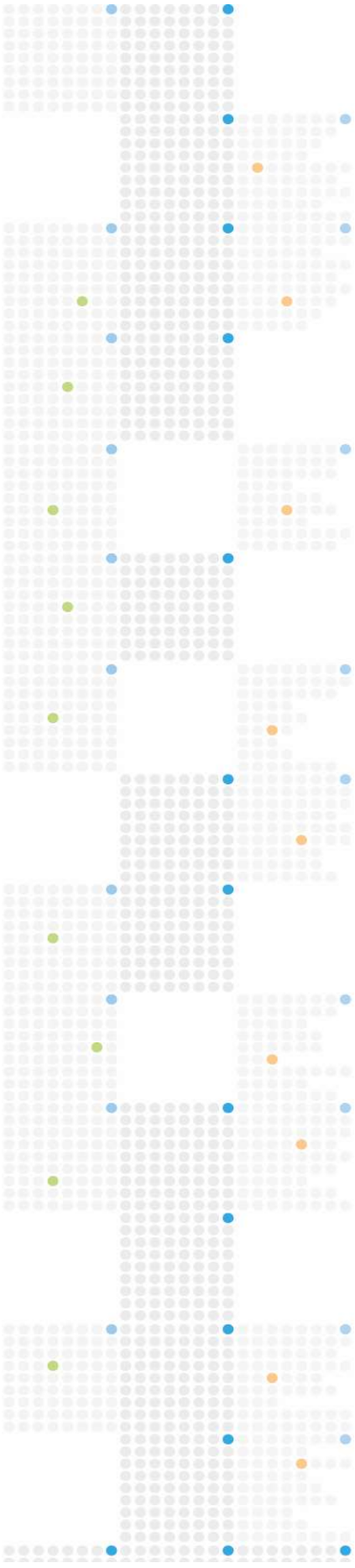
**Abstract**: Driven by innovations in production techniques and tools, factories are becoming more and more flexible. In addition, the growth of technologies such as the Industrial Internet of Things is making production systems holding more and more decisional nodes and entities. Thus, one of the key activities of production management is the efficient scheduling of production tasks. In addition to being a complex combinatorial problem to solve, the nature of the environment makes dynamic scheduling a very challenging problem. This paper addresses the problem of dynamic scheduling of a flexible manufacturing system (FMS), with constraints such as family-dependent setup times and interoperability. To this purpose, the proposed approach combines a set of scheduling rules optimized by an optimization-simulation mechanism. The experiments are performed on two sets of scenarios describing the dynamic arrival of products in the system.

**Key words**: Scheduling ; Hyper ; heuristic ; optimization ; simulation ; Reactive control ; Smart Product

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