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

Proceedings of SOHOMA 2019

Springer

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Preface

This volume gathers the peer-reviewed papers presented at the ninth edition of the International Workshop on Service-oriented, Holonic and Multi-Agent Manufacturing Systems for the Industry of the Future, SOHOMA 2019 organized on 3–4 October 2019 by Universitat Politècnica de València 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 main objective of SOHOMA workshops is to foster innovation in smart and sustainable manufacturing and logistics systems by promoting concepts, methods and solutions addressing trends in service orientation of agent-based control technologies with distributed intelligence.

Following the workshop's technical programme, the book is structured in seven parts that group a number of chapters reporting results of research in the lines of the digital transformation in manufacturing, supply and logistics for reality awareness of control, optimization of production planning and scheduling, process resilience, shop floor agility and sustainability: *Part 1*: Supply Chain 4.0 and the Physical Internet; *Part 2*: Engineering Ethics and Human Integration in Industry 4.0; *Part 3*: Digital Twin for Cyber-Physical Production Systems; *Part 4*: Cloud Manufacturing and Machine Learning Models in Cyber-Physical Production Systems; *Part 5*: Software Design Models for Industrial Automation Systems; *Part 6*: Control Approaches in Cyber-Physical Production Systems for Industry 4.0 and Industry 4.0; *Part 7*: Digital Transformation in Construction, Building Management.

The book aims at shedding light on holonic and multi-agent systems as key enabling drivers of cyber-physical systems and industrial IoT platforms in the Industry 4.0 vision, with focus on: balancing self-organizing solutions for situation awareness and robustness with optimization of the control, flexibility and agility of control architectures, designing for the unexpected, extending digital transformation of industrial processes through digital twins and ontologies bringing thus the ICT and control layers closer to the physical world.

Developing Industry 4.0 control architectures and software requires models and implementing frameworks that are able to provide good production performance and agility to market and product changes (external factors), to mirror the reality of shop floor events (internal factors) and to take intelligent decisions (using human in the loop and machine learning). Holonic and multi-agent approaches provide dynamic feedback from the plant and environment and easy reconfigurable supervising and control solutions. The two implementing frameworks of Industry 4.0—industrial IoT and cyber-physical production system—incorporate cloud services for time-varying aggregation (holarchies) and agent-based information processing at the edge of the systems by reality-reflecting structural elements (products, orders, resources) interconnected as cyber-physical components.

From the reported research, it results that some challenges remain to be dealt with when developing such holonic and multi-agent systems at different levels:

- *Conceptual*: improved design of the control systems based on more abstract and generic understanding and interpretation of holonic architectures, patterns with dynamic switching, increased reality awareness bringing the control layer closer to processes, decision mechanisms for unexpected events, prediction and detection of anomalies based on machine learning, etc.;
- *Societal*: allocation of humans as activity performers without experiencing the penalties to the extent incurred by the IT, human integration in CPS, the autonomy of artificial decisional entities, legal aspects, etc.;
- *Environmental*: adaptation to dynamic environments, energy saving, waste reduction, risk management, etc.;
- *Technical*: high performance computing in the cloud for real-time optimization and predictive maintenance with distribution of intelligence in delegate MAS patterns for robustness at disturbances; service orientation of production scheduling and control processes in the cloud; high availability and cyber-security aspects; in-depth interoperability at physical and information levels; embedding intelligence on products; interaction of control systems and planners with aggregations of digital twins for better access to the world of interest, etc.; and
- *Technological*: efficient integration of new information technologies for implementing solutions: pervasive instrumenting at plant level, resource and product virtualization for workload migration in the cloud, edge and fog computing, software-defined networks, RFID, integrating information and operation technology in the industrial Internet of things, etc.

The theme of the SOHOMA 2019 Workshop is ‘Smart anything everywhere – The vertical and horizontal manufacturing integration’; it stands for abstract things: products, resources and orders that integrate the digital technology.

This theme is related to ‘Industry of the Future’ (IoF), a term used to describe the Fourth Industrial Revolution initiated by a new generation of robotized manufacturing systems conceived to be adaptive, fully connected, analytical and highly efficient. This global IoF model describes a new stage of manufacturing, fully

automatized and using advanced information, communication and control technologies: industrial IoT, cyber-physical production systems, cloud manufacturing, resource virtualization, product intelligence, digital twin, edge and fog computing.

The IoF interconnection of distributed manufacturing entities is presented in a 'system of systems' approach: (i) new types of production resources highly interconnected and self-organizing in the entire value chain, while products decide upon their own production paths and procedures; (ii) new types of intelligent decision-making support available from real-time production data collected from resources and products and machine learning processing.

This IoF approach is based on the digital transformation of manufacturing through cloud services and resource virtualization and allows for intelligent decision-making that complies with the theories of flexibility and reality awareness. These issues are addressed in the book through three domains: big data analytics, machine learning and digital twins.

Big data analytics is related to the digital manufacturing context to acquiring and processing large amounts of shop floor data; three functions are considered when processing data: (1) aggregating at the right logical levels when data originates from multiple sources, (2) aligning the data streams in normalized time intervals and (3) extracting insights from real-time data streams.

Machine learning is a very powerful tool to extract insights from big data; if shop floor data can be obtained in real-time and the machine learning algorithms can be run in a real-time context with re-training on new data (e.g. in the cloud MES), then the insights become predictions, enabling real-time decisions.

The holistic view of the capabilities and features of a device/product including its digital representation, execution context, history of behaviour and time evolution can be encapsulated in a digital twin defined as a virtual model in the cloud of a product, process, physical asset, that is persistent even if its physical counterpart is not always on line/connected; this extended digital model can be aggregated in reality-aware control, optimized planning, predictive maintenance, etc.

The scientific event reflected in this book draws on research developed recently in the scientific community SOHOMA and by other groups from industry:

- New paradigms and implementing solutions for digital automation in manufacturing;
- Cloud manufacturing systems (CMfg)—integrated enterprise solutions; Digital Manufacturing on a Shoestring (MSs)—low-cost digital solutions for SMEs;
- Holonic architectures and multi-agent frameworks for smart, safe and sustainable industrial systems;
- Intelligent products, orders and systems in industry;
- Service orientation of control and management in the manufacturing value chain;
- Issues of agility, flexibility, safety, resilience and reconfigurability in industrial systems with new service-oriented IC^2T: cloud, Web, SOA;
- Cyber-physical production systems and industrial IoT for Industry 4.0.

The papers grouped in the seven parts of the book have in common concepts, methodologies and implementing frameworks of new service-oriented information, communication and control technologies applied for the development of cyber-physical production systems, industrial Internet of things architectures, cloud manufacturing platforms, digital twins aggregated in monitoring, control and maintenance tasks, and pervasive shop floor device instrumenting and interconnecting with edge and fog computing devices.

In the workshop's perspective, the digital transformation of manufacturing is placed in the general framework of Industry 4.0 or "Industry of the future" by including the actual vision and initiatives of developing architectures and core control technologies for production processes based on a wide-ranging, Internet-scale platform linking scalably and interoperably technology providers, manufacturing system designers, shop floor systems, supply chains and service providers. This vision enables the emergence of a sustainable Internet economy for industrial production—strongly connected to the reality, robust at disturbances, agile relative to markets and customer-oriented.

The research works reported in this book suggest that the most natural solutions for the digital transformation of manufacturing in the Industry 4.0 vision are to virtualize shop floor devices (e.g. resources, products and orders) and use virtualized cloud services coupled with the newer edge and fog computing hardware and software solutions. Recent research applied to industry emphasizes the need for securing the dual cyber-physical space. Inter-enterprise data networks are modelled here having SDN characteristics, such that manufacturing data packets are under a centralized logical control reducing the likelihood of data theft and network delay or failure.

The application space for these new developments proved to be very broad. The workshop SOHOMA 2019 addressed aspects of industrial systems management and control including:

- Control and management of manufacturing, supply chain, logistics, transportation, constructions, and large-scale services;
- Production and after-sale services, maintenance and repair operations;
- Monitoring energy consumption, energy-aware control of industrial processes;
- Implementation case studies of digital manufacturing control solutions in the CMfg and MSs' frameworks.

The rapid digitalization and smart integration of shop floor devices caused an explosion in the data points available in large-scale manufacturing systems. The degree at which enterprises are capable to extract useful insights from it represents a differentiating factor on sustainability and development.

This consideration reinforces the necessity to bring closer the reality-reflecting part and the decision-making part of manufacturing control. The research presented in this book assesses reference models and architectures (industrial IoT models, cloud manufacturing models, semi-heterarchical planning and control models, etc.) while focusing on their world of interest. This implies on one hand intensive use of

digital twins—models of processes, resources and products with extended behavioural and operating descriptions in space and time—and on the other hand the use of machine learning for knowledge and information extraction, prediction and anomaly detection at aggregated level—e.g. in the cloud MES for optimized decision-making.

All these aspects are discussed in the present book, which we hope you will find useful reading.

June 2019

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