

Control issues in the cyber-physical manufacturing enterprise

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“Control issues in the cyber-physical manufacturing enterprise”

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Manufacturing is nowadays experiencing a transition that is fostering new opportunities and issues in the control engineering field. Emerging new approaches are enabled by Industrial Internet-of-Things (IIoT) and Cyber-Physical Systems (CPS) technologies and methods. The smart, sensing, and sustainable enterprise (S^3 Enterprise) is a digital business innovation concept building on technologies like IIoT and CPS for aggregating data from and to intelligent sensors and actors. Agent-based Middleware, Message-based Middleware, Service-oriented Architectures are key technologies that promote the structuring and organisation of distributed systems. New AI- and model-driven approaches enhance the support to the human decision makers, enabling agile, flexible, and proactive management of the enterprise. The S^3 Enterprise requires new capabilities enabled by next-generation information systems to perform sensing, modelling, analysis, and interpretation of “any” signal, with real-time data gathering and analysis and/or with offline historical data series elaboration. The data and intelligent algorithms support flexible, and autonomous adaptation of the enterprise to the changing needs of the business and socio-technical context.

In this context, human operator and computing technologies are relevant assets to build intelligent control in the S^3 Enterprise. The human operator, interacting with intelligent systems, is constantly monitoring, and re-configuring complex manufacturing and production systems. Cloud and edge-computing technologies have a significant impact on the design and implementation of these systems-of-systems; indeed, they bring the required computing power to manufacturing and production systems, supporting also digital business innovations in the S^3 Enterprise. These trends lead to an increasing number and diversity of systems that need to work together in the future enterprises. In this evolving context, the capability to handle a complex and dynamic system requires a shift from classic approaches of central control of systems, towards systems-of-systems interoperability as a basis for distributed and collaborative control. This shift will have consequences on future enterprise architectures as a basis for control of such systems. Furthermore, it will bring new control and management practices thanks to the CPS applications supporting decisions and actions in key areas of the manufacturing enterprise as operations and logistics management, and product and asset lifecycle management.

The special section of this issue of Annual Reviews in Control, is composed of extended versions of 6 selected best papers published in open invited tracks of the IFAC TC 5.1 “Manufacturing Plant Control” and the TC 5.3 “Integration and Interoperability of Enterprise Systems” at the IFAC World Congress 2020, Berlin.

The first paper, entitled “Interoperability in the Cyber-Physical Manufacturing Enterprise”, by Georg Weichhart, Hervé Panetto, and Arturo Molina, explores models supporting cyber-physical enterprise systems with respect to online decision-making based on up-to-date data, requiring networked sensor and actor systems in place. In this paper, the authors survey approaches on Enterprise Interoperability with special attention to the Cyber-Physical Manufacturing Enterprise. The paper identifies the need for interoperability of individual systems in a system-of-systems in contrast to the integration in a single system. Also identified are issues due to insufficient support for modelling physical aspects of systems. An application scenario from the manufacturing domain serves to underpin the developed approach.

The second paper, entitled “A decision-making framework for dynamic scheduling of Cyber-Physical Production Systems based on digital twins” by Alberto Villalonga, Elisa Negri, Giacomo Biscardo, Fernando Castano, Rodolfo Haber, Luca Fumagalli, and Marco Macchi, deals with one important challenge in manufacturing

systems, the updating of dynamic production schedules through an automated decision-making performed while the production is running. The state of the manufacturing system may in fact lead to schedule unfeasibility or inefficiency, thus requiring responsiveness to preserve productivity and reduce the operational costs. To face current limitations of traditional scheduling methods, this work proposes a new framework that exploits the aggregation of several digital twins, representing different physical assets and their autonomous decision-making, together with a global digital twin, leading to the production scheduling optimization when needed. The decision-making process is supported by fuzzy logic and considers the state of the different assets and the production rate of the system. The condition of the assets is predicted by the condition-based monitoring modules in the local digital twins of the workstations, whereas the production rate is evaluated and assured by the global digital twin of the shop floor. The proposed framework is validated in an Industry 4.0 pilot line. The work demonstrates that the proposed framework is capable to detect changes in the manufacturing process and to make appropriate decisions accordingly.

The third paper, entitled "Monitoring on a Shoestring: Low Cost Solutions for Digital Manufacturing" by Gregory Hawkridge, Anandarup Mukherjee, Duncan McFarlane, Yedige Tlegenov, Ajith K. Parlikad, Nicholas J. Reyner, and Alan Thorne, presents some insights for the enterprises digital transformation that can provide a competitive edge for many manufacturers. However, many smaller companies may not have the capabilities needed to embrace this opportunity and may be left behind. The Digital Manufacturing on a Shoestring programme is attempting to alleviate this by creating a low-cost pathway to help manufacturing small and medium sized enterprises (SMEs) engage with digitalisation. This paper focuses on industrial monitoring and explores the potential for developing simple monitoring systems that solve real operation challenges in SMEs using low-cost, off-the-shelf technologies. A blueprint for developing such systems is presented and then exemplified through a case study system. The paper concludes that low-cost monitoring can be feasible given the right application and operating environment.

The fourth paper entitled "Information Modelling with focus on existing Manufacturing Systems" by Sebastian Schmied, Selvine G. Mathias, Daniel Großmann, Ralph Klaus Müller, and Ulrich Jumar, discusses the requirement for manufacturing systems to frequently being adapted to changes. To support these, a standardized, semantic exchange of information between all components of the system is crucial. An information model describing all information available within the manufacturing system together with a common middleware protocol can fulfil this requirement. To create an information model, it is relevant to identify information objects and their relations to each other. The implementation of a common address space requires further concepts like dynamic aggregation of entities. Therefore, this paper describes a methodology for information model creation including versioning compliant modelling and integration of existing standards. Further, steps for implementation as validation and dynamic aggregation of instances are described. The results of this approach have been discussed along with the proposal for further directions and an application example.

The last paper, entitled "MBSE and Cloud Computing Based Industrial Design and Development Software System Architecture", by Chao Yu, Qing Li, Kui Liu, Yuwen Chen, and Hailong Wei, proposes a model-based systems engineering (MBSE) and cloud computing based industrial design and development software system architecture absorbing the emerging manufacturing methods and technologies. Oriented to new generation of cyber-physical manufacturing, the MBSE double-Vs model is refined as methodology in re-engineering complex product design and development process. This system restructures on-premises software architecture to cloud-based which matches with the development trend of modern industry like IIoT and CPS. The establishment process of this system architecture also provides a basic framework for the integration of various industrial services. At the end of the paper, as an example of actual cases, a FMS design and development platform is

The editors of this special section of Annual Reviews in Control would like to express their gratitude to the authors for their excellent contributions. We are also very grateful to all reviewers who have dedicated efforts in reviewing these papers, and for their valuable comments and suggestions that significantly improved the overall quality of the contributions. We hope that this special section will serve as a good reference for researchers, scientists, engineers, and academicians in the field of the industry of the future.