Guest Editorial
Distributed Data Processing in Industrial Applications

INDUSTRIAL applications become more and more distributed. The "intelligence" is embedded in smaller and smaller devices connected via various types of computer and communication networks. This is possible due to the strong development of processing infrastructure as well as information and interconnection technologies. As a result, systems simply get "smarter," both from the user's and developer's point of view. They can handle more data in more sophisticated ways. They are able to deliver functionalities and services which were not even thinkable ten years ago. Temporal characteristics of data processing in distributed applications are obtainable as more in line with the requested ones. Finally, they can be created with tools, methods, and standards providing better support in the domain of modeling, simulation, validation, and other aspects of designing, testing, and commissioning. Taking into consideration the last decade, it can be claimed that the increasing usage of system architectures based on dispersed applications is a constant trend.

Thus, the further perspective of distributed processing in industrial systems is promising. As usual, the advances in distributed data processing will be propelled by requirements imposed by production quality, efficiency, sustainability, flexibility, and new industrial technologies. The current stage of research in the domain is on the verge of another breakthrough. The old approaches that are still widely used reached the mature stage. Many existing solutions are based on technologies invented in the 1990s and before. For instance, recent statistical reports show that systems worth more than 50 billion dollars worldwide are more than 20 years old [1].

This also pushes for the continuous development of new IT technologies, and despite the natural inertia in automation, they are being introduced into new solutions. Moreover, there is strong drive in industry to design, create, and analyze systems in entirely new ways.

Currently, automation systems are mostly designed based on distributed architectures. In a typical approach, such systems are considered as a set of various computerized nodes, physically scattered on the shop floor, and connected together via computer networks [2]. The whole system, seen as a holistic but abstract entity, delivers several functionalities needed for the control and maintenance of a technological process. The system is processing information coming from a given industrial process. Information is coded as a set of data in the form of application variables allocated in the memory of the constituent devices. A needful subset of the data is exchanged between applications in order to ensure their proper collaboration. The data are transferred internally within each local system as well as externally to the other systems.

The industrial networks are the only means being able to deliver local and remote communication services in real time. Control functionalities are delivered by algorithms implemented in the form of programs executed within system nodes.

These briefly presented paradigms represent a typical model of an automation system that is designed and used as a separate part of factory IT structures [3]. This model is known as a pyramid model, in which shop floor systems are located at the bottom. There are many issues related to such a model. In practice, the issue of the real-time delivering of input/output data to the relevant processing units (e.g., programmable logic controllers) is the most frequently considered one. Data are locally processed by resources of system nodes, but their applications communicate in order to exchange shared data and mutually synchronize as well. This model is popular due to the pretty big number of existing industrial applications based on it, as well as commonly used due to the inertia in the evolution of such applications. There is a wealth of research relating to time-constrained communication and data processing in such a model. Technologies referring to a local and homogeneous approach in automation are valid and important, but mostly mature. For industrial use cases, such technologies are usually sufficient, even if they are often still suboptimal in detail and leave room for further innovation with the goal of increasing efficiency or performance.

However, despite the commonness of physical implementations and the maturity of the research state, it is not the only approach these days. A more interesting aspect of distribution is the scattering of functional parts of the system and the virtualization of its instances, especially with isolation from actual devices during the design process. Currently, new IT technologies allow creating solutions for distributed data processing with consistent and multiservice communication and dispersed system application that operate in a multifunctional scope. The data flow in modern factories is based on information model and services tailored to the requirements coming from given functionalities. Many companies look for methods of redesigning the system in a short time and ways to provide its effective coexistence and collaboration.

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There are many scientific and commercial projects released in this area. An example is the EU project “ICT for the Factory of the Future” as well as other projects referring to topics with energy consumption as an aim. Moreover, in 2013 a new edition of the IEC 61499 standard has been released. It improves the previously announced architectural and implementation patterns referring to distributed systems in industry. The IEC 61499 is a potential platform for creating many interesting tools on industrial communication technologies, distributed data processing, system and data flow modeling, and system integration [4], [5].

The new paradigms can be useful for increasing the flexibility of the structure and a functional scope of computerized and networked control systems used in production. A modern and competitive plant needs to use systems being able to reconfigure their internal and external relationships in a reasonable time. It is requested in order to change the production of a given product to a different one in a very flexible way [6]. This refers to a subtype of such a product or its customization, as well as to the modification of the whole production, due to either technology changes or releasing a new product. In a competitive market flexibility can be considered a crucial feature. Especially, the ability to reconfigure without a significant influence on the running system and/or without a negative impact on the business processes is of the utmost importance.

A further requirement being able to handle new approaches is the management of power consumption. Usually, there are many logical relations between the operations of physical system components. The key functionalities of the distributed application can be supported by additional tasks that are responsible for detecting the current state of consumption and coordinating the power supplying schemas.

Another research area in the domain of the distributed data processing is involving the second and the third generations of industrial networks [2], [7] in creating highly heterogeneous systems with functional and territorial distribution of its nodes and running processes. This can extend the system’s operating area to external, vast and almost unlimited public zones based on Internet and cellular networks, as well as to very close range access based on personal networking. As a result, cyber-physical systems were developed in which distributed control processes cooperate on physical resources via networks in real time. The main challenge in this case is assuring real-time services, as well as reliability and security of communications [8], [9].

Two new and popular ideas are directly connected with this. The first one is Internet of Things (IoT) and the second one is cloud computing used together with virtualization.

The IoT idea is commonly considered very attractive [10], [11]. However, in the case of networked systems in industry a well-known problem of heterogeneity exists, both on the hardware and software layers. Thus, the main issue to be solved is to propose a technology that is independent from the platform specificity. This can be done, e.g., as a virtualized network layer or as middleware architecture.

Virtualized control based on extended factory cloud is technically possible. The main problem is to manage the communication via available network means including known and defined factory infrastructure and unknown and undefined public internets, in order to achieve the requested temporal characteristic of delays and jitters. Thus, it is hard to find the real application of such a concept and most of considerations are only theoretical or simulated. However, this area has great potential [12]. Nonetheless, the virtualization technologies seem to be used as a part of classical control systems, both in virtualized networks and virtualized processing resources.

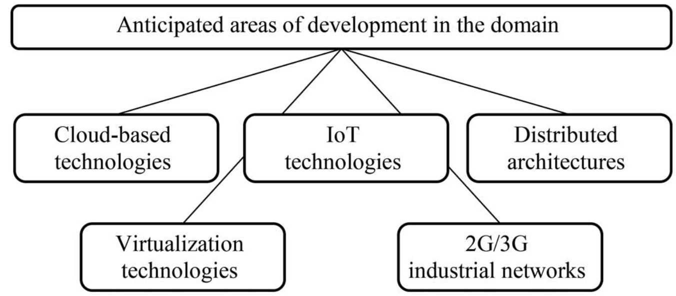

Fig. 1. Estimated areas of technological advancement in the domain of distributed data processing in industrial applications.

Finally, it is worth mentioning that not only brand-new ideas should be considered progress in the domain of distributed data processing. The modern and currently used techniques as real-time Ethernet protocols, wireless networking, and interoperability platforms can become a subject of research in order to make a given solution evolve and constantly improve. The Profinet Isochronous Real Time (IRT) version 2.3 with dynamic frame packing (DFP) upgrade is a good example. Similar examples are the controller area network (CAN), EtherCAT, long tern evolution (LTE), OLE for process control (OPC) improvement attempts [13], [14], the research on wireless and wireless sensor networks (WSN) utilization [15], or even adapting the existing paradigms and techniques, oriented to some other kind of systems, such as the service oriented architecture [16]–[18], Web services [19], [20], HTTP [21] usage, and others.

Fig. 1 presents a summary of expected areas of development that are currently being considered. Potentially, they seem to offer promising advantages. However, it will take much time and research effort to prove this.

This Special Section on distributed data processing in industrial applications tackles a wide range of the issues mentioned above. The main objective is both bringing together ideas of the worldwide research community about one common platform and presenting the latest advances and developments in design, modeling, programming, management, and innovative implementations of distributed information systems, including the latest works related to industrial communication technologies to be used in the future.

Four papers have been selected for publication in this Special Section. In the first one [22], the authors refer to the problem of low efficiency of EtherCAT aperiodic real-time transmissions. They propose a general framework for prioritized swapping-based scheduling of aperiodic messages. The proposed solution extends the standard EtherCAT services adjusting them to event-triggered control applications. The achieved results are proved by simulations in the OMNeT++ framework.

The second paper [23] concerns the issue of determining the locations of WSN nodes in high interest areas that require high density of nodes. The authors propose a new approach to cover this problem. The testing of the proposed AFECETS algorithm provides the results that meet the requirements of the arbitrary domain coverage along with delivering a significantly reduced number of nodes with improved spacing and full coverage of the considered area.

In the third paper [24], virtualized PC stations are described as the means for improving the security and responsiveness of the PC-based industrial software. The results are presented as comprised measurements of station reactions in real and virtualized cases, based on physical industrial devices and software. The results show that the distribution of some typical functionalities of SCADA, OPC, or a database can bring better temporal characteristics of the responsiveness of virtualized stations than of real ones.

The fourth paper [25] refers to the practical achievement of the distributed system flexibility by using the SOA and the IEC 61499 standard. In the paper, the architecture of the execution environment with the dynamic reconfiguration ability is presented. The authors built the environment in a way that allows dynamic creation and deletion of any function block types and its instances without interrupting the runtime.

A Special Section like the present one requires the support of many people. We would like, first of all, to thank all the authors who have submitted papers to the Special Section for their contribution and support, we are truly grateful for the efforts and patience of the reviewers whose expertise contributed significantly to the quality of the papers that finally made their way into this section. Finally, special thanks go to the TII Editorial team for the generosity and direct support from the first idea until its publication.

PIOTR GAJ, *Guest Editor*
Silesian University of Technology
Gliwice, Poland
e-mail: piotr.gaj@ieee.org

ALEKSANDER MALINOWSKI, *Guest Editor*
Bradley University
Peoria, IL USA
e-mail: olekmali@bradley.edu

THILO SAUTER, *Guest Editor*
Danube University Krems
Wiener Neustadt, Austria
e-mail: thilo.sauter@donau-uni.ac.at

ADRIANO VALENZANO, *Guest Editor*
National Research Council of Italy
Torino, Italy
e-mail: adriano.valenzano@polito.it

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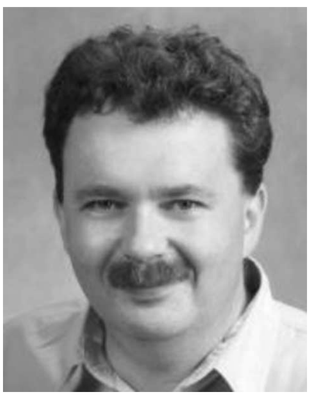
Piotr Gaj (SM'13) received the M.S. and Ph.D. degrees (with highest honors) in informatics from the Silesian University of Technology (SUT), Gliwice, Poland, in 1994 and 2003, respectively.

He is currently a Lecturer with the Faculty of Automatic Control, Electronics, and Computer Science, SUT. He is the author of many technical papers. His research interests include industrial computer networks and distributed systems.

Dr. Gaj has been an Associate Editor for the IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS since 2013. He is the Chair of the Computer Networks International Science Conference.



Aleksander Malinowski (SM'00) received the M.S. degree in electronics from the Gdansk University of Technology, Gdansk, Poland, in 1990, and the Ph.D. degree (with highest honors) in computer science and engineering from the University of Louisville, Louisville, KY, USA, in 1996.

His research interests include networked cyber-physical systems, Internet of Things, network-based control systems, real-time operating systems for small embedded platforms, as well as computational intelligence and neural networks.

Dr. Malinowski is a Senior Administrative Committee Member of the IEEE Industrial Electronics Society. He received the the Binford Memorial Award.

Thilo Sauter (SM'09–F'14) received the Dipl.-Ing. and the Ph.D. degrees in electrical engineering from the Vienna University of Technology, Wien, Austria, in 1992 and 1999, respectively.

Currently, he is the Head of the Center for Integrated Sensor Systems, Danube University Krems, Krems an der Donau, Austria, and an Associate Professor with the Vienna University of Technology. His research interests include integrated circuit (IC) design, smart sensors, and automation networks with a focus on real-time, security, interconnection, and integration issues.

Adriano Valenzano (SM'09) received the Laurea degree in electronic engineering from the Politecnico di Torino, Turin, Italy, in 1980.

He is a Director of Research with the National Research Council of Italy (CNR), Rome, Italy. Currently, he works with the Institute of Electronics, Computer, and Telecommunication Engineering (IEIIT), Turin, Italy, where he is responsible for research concerning distributed computer systems, local area networks, and communication protocols. He has co-authored approximately 200 refereed journal and conference papers in the area of computer engineering.

Dr. Valenzano has been serving as an Associate Editor for the IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS since 2007. He was the recipient of the 2013 IEEE Industrial Electronics Society Award and the ABB Lifetime Contribution to Factory Automation Award.