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Editorial

Emerging Paradigms and Architectures for Industry 5.0 Applications

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1. Introduction

After the success of the first Special Issue on "Emerging Paradigms and Architectures for Industry 4.0 Applications" [1], a new Special Issue was launched to update the approach followed by the Fourth Industrial Revolution (4IR), with the primary goal of fostering the path towards the Fifth Industrial Revolution (5IR), known as "Industry 5.0" in Europe. This new paradigm complements the existing Industry 4.0 principles by driving the transition to a sustainable, human-centered, and resilient industry. 5IR-enabling technologies such as Industrial Cyber-Physical Systems (ICPS), the Industrial Internet of Things (IIoT), novel computing paradigms (e.g., fog, mist, and edge computing), Distributed Ledger Technologies (DLTs) (e.g., blockchain), digital twins, or augmented/mixed reality technologies, allow for developing novel cyber-secure, resilient, collaborative and human-centric advanced manufacturing systems. Such systems focus on the continuous improvement of the manufacturing processes, by taking advantage of several relevant digitalization-related aspects at the data level (e.g., collection, communication, and storage), at the system's operational level (e.g., reliability, scalability, real-time performance, and energy efficiency), and at the systems' integration level (e.g., interoperability, standardization, and security by design).

In this second edition, this Special Issue collected papers that aim at reporting the latest advances in architectures, paradigms, and applications in the ever-increasing complex ecosystem of green smart manufacturing. A total of five papers (two research papers and three review papers) were presented in this Special Issue, related to various Industry 5.0 related areas, like Low-Power Wide-Area Network (LPWAN) technologies, power management, IIoT, CPSs, or blockchain.

Sustainability, and specifically, circular economy, is the research aim of [2]. The circular economy is, together with digitalization, a factor that will enable future European competitiveness. It clearly represents a market opportunity for European industries, mainly composed of strong but highly fragmented small and medium-sized enterprises (SMEs), which account for 99% of all businesses in the European Union (EU). Such an ecosystem gives rise to the proliferation of numerous commercial platforms for digitalized manufacturing. Although there are some promising works undergoing, value networks do not operate in a seamless, transparent, and effective way. Pedrazzoli et al. [2] identified six challenges that need to be addressed in order to successfully deploy a manufacturing platform that supports value networks operating in a circular economy framework. Thus, the article describes a vision for this platform as an ecosystem of open platforms and commercial solutions aimed at filling the identified gaps. The paper presents the foundations for an International Data Space (IDS) manufacturing platform based on FIWARE technology and aims at empowering a fully digital circular economy.

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The problem of accessing to trustworthy, transparent, and reliable information is studied in [3]. Specifically, the article analyzes a use case related to government inspection agencies, which monitor the concentration of fine dust at construction sites through IoT devices, but the verification that adequate reduction measures are being considered is still difficult, since contractors may submit false reports. In addition, since the centralized monitoring system is under government management, access to information is difficult (e.g., it is not an open platform). In order to solve the aforementioned issues, Cho et al. propose a blockchain-based network concept model for the development of fine dust management systems at construction sites. The system provides all the stakeholders (e.g., contractors, government inspection agencies, and citizens) with information associated with IoT data and fine dust reduction measurements. For the operation of the blockchain network, a chaincode was designed, a Decentralized Application (DApp) (i.e., a client application that runs on the blockchain network) was developed, and the network architecture was devised. Furthermore, information on fine dust concentration and photos of the reduction measures were shared with the stakeholders through Hyperledger Explorer, a blockchain search tool.

The use of the IoT and CPSs to develop cognitive buildings is analyzed in [4]. Recent advances in IoT ecosystems enable the integration of sensors, computing, and communication capabilities into low-cost, small-scale devices that can be used to implement CPSs to perform real-time radon gas management. Such management systems are important since radon gas is a pollutant with an adverse influence on public health. Moreover, the mentioned technologies are relevant for building management systems that focus on balancing factors, such as energy efficiency, radon exposure management, and user experience, to achieve a more seamless integration between technology and the built environment. Thus, the work in [4] overviews the basic concepts and the legal framework regarding indoor radon gas exposure, as well as its relationship with energy efficiency. It also reviews recent IoT technologies for indoor radon gas monitoring, assessment, and mitigation. Finally, it discusses the main opportunities and challenges.

Low-Power Wide-Area Network (LPWAN) technologies are the topic chosen by [5]. In the last years, LPWAN technologies have received a lot of attention from the research community in large outdoor deployments due to their low power consumption, low cost, and long-range communication. Such technologies are able to perform communications and device positioning simultaneously, thus reducing not only the cost of deployment but also the power consumption of IoT devices. Three LPWAN communication technologies are analyzed (LoRaWAN, Sigfox, and NB-IoT), which are widely used in various IoT application domains. The article also covers the IoT application fields of smart cities, smart transportation, smart healthcare, and smart manufacturing. Each of the application domains has different requirements, with the provision of location information being relevant in asset tracking and management. In addition, the work in [5] explores low-cost non-GNSS outdoor localization techniques. In particular, the authors analyze the systems that make use of such techniques, defining their requirements and restrictions when used in IoT applications and describing the most relevant outdoor location methods without GNSS (focusing on LPWAN technologies). Furthermore, the most relevant methods to improve location accuracy without GNSS in IoT applications are studied, and the main open challenges and future research directions are detailed.

Finally, the work in [6] focuses on power management. Thus, the paper provides an extensive literature review of the recently published articles related to methods to reduce power consumption and cost. The article deals with several topics, such as battery management, the energy mix between renewable energy and other energy sources, big data in smart grids, and intelligent cloud-based power optimization intelligent systems. It is discussed how a well-maintained system of power mixing can lead to improving environmental results by reducing the carbon footprint. Furthermore, a framework of the charge controller system is provided to monitor and combine different energy sources in order to obtain the best-optimized system, control the switches in the energy hub, and manage the charging and discharging process.

Although submissions for this Special Issue have been closed, more in-depth research in the field of Industry 5.0 is still needed to address some of the following open challenges:

- Novel architectures for the Green Industrial Internet of Things (GIIoT);
- Industrial applications of the Green Internet of Things (GIoT);
- Cybersecurity in IIoT environments;
- Cognitive IIoT;
- Fog, mist, edge, and mobile edge computing architectures for industrial scenarios;
- Industrial cyber–physical human systems (ICPHSs) and digital twins;
- Advances in the application of distributed ledger technologies (DLTs) (e.g., Blockchain, IOTA) to industrial scenarios;
- Energy-harvesting techniques for industrial scenarios;
- Green machine learning and artificial intelligence for Industry 5.0;

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Abbreviations

The following abbreviations are used in this manuscript:

4IR	Fourth Industrial Revolution
5IR	Fifth Industrial Revolution
CPS	Cyber–Physical System
DApp	Decentralized Application
DC	Direct Current
DLT	Distributed Ledger Technology
EMS	Energy Management Systems
IoT	Internet of Things
LPWAN	Low Power Wide Area Network
RE	Renewable Energy
SMEs	Small and medium-sized enterprises
AI	Artificial Intelligence

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