# Guest Editorial Special Section on Cloud Computing, Edge Computing, Internet of Things, and Big Data Analytics Applications for Healthcare Industry 4.0

INDUSTRY is the part of an economy that produces material goods and services that are highly mechanized and automatized. From the early stage of industrialization, technological advances have led to four paradigm shifts called "industrial revolutions." The first industrial revolution regarded mechanization based on water and steam power, the second one regarded the intensive use of electrical energy to maximize massive production based on assembly lines, the third one regarded the widespread digitalization thanks to computer-aided automation, and the fourth one (which is currently happening) regards instead the combination of future-oriented technologies including cyber-physical systems (CPS), cognitive computing, cloud computing, Internet of Things (IoT), big data analytics, and edge computing, among others [1], [2].

Industry 4.0 principles have found a great consensus and adoption in different industrial domains including healthcare. Healthcare Industry 4.0 allows increasing flexibility in production, speeding up both manufacturing and market processes, increasing both the product quality and productivity, and changing business models modifying the interaction with value chain, competitors, and clients. Healthcare Industry 4.0 requires investments and mind-set change for cross-industry collaboration, agreements on data ownership, security, legal issue solving, product registration standards, new machine-to-machine communication protocols, and employment/skills development. Furthermore, Healthcare Industry 4.0 is revolutionizing the market of health service provisioning to patients and clinical operators. In fact, all over the world, the number of investments in information and communication technology (ICT) for health and wellbeing (eHealth) is rapidly increasing. In fact, GLOBE NEWSWIRE has predicted that the global eHealth market is expected to reach 308 billion dollars by 2022 [3].

In this context, there is growing interest around the adoption of recent cutting-edge ICT technologies in Healthcare Industry 4.0, including cloud computing, IoT, big data analytics, and edge computing, that allow the delivery of various kinds of eHealth services and applications over telecommunication networks and the Internet remotely. Therefore, besides revolutionizing the whole healthcare industrial production cycle, Healthcare Industry 4.0 allows, on one hand, patients to experience advanced telemedicine (e.g., telenursing, telerehabilitation, teledialog, telemonitoring, teleanalysis, telepharmacy, teletrauma care, telepsychiatry, teleradiology, telepathology, teledermatology, teledentistry, teleaudiology, teleophthalmology, and so on) services and applications directly in their homes by means of medical IoT devices equipped with sensors and actuators interacting with cloud and edge computing services able to process big health data and connected with hospitals and clinical centers. On the other hand, clinical operators can remotely provide patients with real-time healthcare assistance, dynamically improving therapies.

This Special Section on "Cloud computing, edge computing, internet of things and big data analytics applications for Healthcare Industry 4.0" of the IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS tackles the main research issues in the development, adoption, and application of eHealth initiatives in the field of Healthcare Industry 4.0. The selected eight high-quality contributions cover a broad spectrum of topics for Healthcare Industry 4.0, including novel technologies and application scenarios. In fact, along with papers proposing comprehensive innovative solutions for patient care and telemedicine, the Special Section also includes papers dealing with emerging topics such as smart pharmaceutical factory, healthcare architectures, healthcare service provisioning, and healthcare security, which introduce novel challenges in Healthcare Industry 4.0.

The paper "Brain network analysis of compressive sensed high-density EEG signals in AD and MCI subjects" by Mammone *et al.* deals with the construction of a complex network model of the brain-electrical activity using high-density electroencephalogram (HD-EEG) recordings and a comparison among the network organization of Alzheimer's disease, mild cognitive impaired, and healthy control (CNT) patients. Compressive sensing was adopted to compress and reconstruct the HD-EEG signals with minimal information loss, proving that the compression does not alter the results of the complex network analysis. In particular, when applied to the reconstructed HD-EEG, the complex network analysis provided a substantially unaltered performance, compared to the analysis of the original signals.

Digital Object Identifier 10.1109/TII.2018.2883315

The paper "Serious games and in-cloud data analytics for the virtualization and personalization of rehabilitation treatments" by Caggianese *et al.* deals with the unsustainable economic impact of healthcare systems caused by the significant increase in the number of patients generated by rehabilitation, implying a reduction in therapeutic supervision and support for each patient. To address this problem, a telerehabilitation system based on serious games and cloud-based big data analytics services, in accordance with Industry 4.0 design principles, is discussed. The system takes the advantages of modularity, service orientation, decentralization, virtualization, and real-time capability, and it is aimed at poststroke patients. It includes components for real-time acquisition of patient's motor data and a decision support service for their analysis. Furthermore, a pilot study proves its validity.

The paper "Reconfigurable smart factory for drug packing in Healthcare Industry 4.0" by Wan *et al.* deals with a data-driven reconfigurable production mode of smart factory for pharmaceutical manufacturing in the context of Healthcare Industry 4.0. It exploits cyber-physical systems (CPS) in order to accommodate the increasing requirements of flexibility, agility, and low cost in the healthcare sector. The architecture of the smart factory consists of three main layers, i.e., perception layer, deployment layer, and executing layer. A manufacturing semantics ontology is also introduced, which is responsible for plan scheduling of pharmaceutical production. The reconfigurable plans are generated from the production demand of drugs, as well as the information statement of low-level machine resources.

The paper "A continuous non-invasive arterial pressure (CNAP) approach for Health 4.0 systems" by Sannino *et al.* deals with the problem of estimating blood pressure values of subjects in a continuous, real-time, and noninvasive way. Specifically, the approach only requires a photoplethysmography sensor and mobile/desktop IoT devices to collect observations and adopts genetic programming to automatically find an explicit relationship between photoplethysmography and blood pressure values with minimal errors.

The paper "An innovative methodology for big data visualization for telemedicine" by Galletta *et al.* deals with a graphical tool for the visualization of big health data that can be easily used for monitoring health status of patients remotely allowing clinical operators to monitor the current status of a patient by means of a graphical interface based on colored circles.

The paper "An edge-based architecture to support efficient applications for Healthcare Industry 4.0" by Pace *et al.* deals with an edge-based architecture, i.e., BodyEdge, to support time-dependent applications in Healthcare Industry 4.0. It consists of a tiny IoT mobile client module and a gateway supporting multiradio and multitechnology communication to collect and locally process data coming from different scenarios. In addition, it also exploits the facilities made available from both private and public cloud platforms in order to guarantee high flexibility, robustness, and adaptive level of service.

The paper "SAFE: SDN assisted framework for edge-cloud interplay in secure healthcare ecosystem" by Aujla *et al.* deals with a piece of software-defined networking (SDN)-assisted framework for edge-cloud interplay in secure healthcare ecosystem (SAFE). The objectives of SAFE include an offloading scheme to support edge-cloud interplay, an SDN-assisted virtualized flow management scheme, and a secure lattice-based cryptosystem.

The paper "Provably secure fine-grained data access control over multiple cloud servers in mobile cloud computing based healthcare applications" by Roy *et al.* deals with a secure mobile user authentication mechanism and a fine-grained level access control for mobile cloud computing in the context of healthcare. It helps analyze, in a secure fashion, data regarding the patients' records and also in extracting recommendations in healthcare applications.

Summarizing, the selected eight high-quality papers address several important areas, challenges, and novel approaches toward Healthcare Industry 4.0, as well as future challenges toward new and more demanding application scenarios. We hope this Special Section can contribute to increasing the interest of both academic and industrial communities about the Healthcare Industry 4.0 research.

## Acknowledgment

We, the Guest Editors, would like to express our deep gratitude to all the authors who submitted their scientific works as well as to the highly qualified reviewers who provided thorough reviews and comprehensive comments, thus significantly contributing to the high quality level of the papers that were finally accepted for publication. We would like to thank the Editor-in-Chief, Prof. R. Luo, of the IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS (TII) for his support and guidance in preparing and finalizing this special section. We are also grateful to the whole TII staff for the professional support provided.

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