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A Survey on the Concepts, Trends, Enabling Technologies, Architectures, Challenges and Open Issues in Cognitive IoT Based Smart Environments

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ABSTRACT

In many industrial applications, novel paradigms based on IoT services are evolving. However, today's industrial systems are facing various challenges, due to heterogeneous, mixed and uncertain ubiquitous network, the application prospect of which is extensive in the field of modern intelligent service, and discrepancies between service offering and application requirement. In line to this, the researchers believed that existing technologies and approach specifically, IoT, lack enough cognitive based intelligence and cannot achieve the expected enhancements and smart industry developments.

Therefore, the researchers argue that, with ambition to optimize the resource and infrastructures invested for smart industries, the Cognitive Internet of Things (CIoT) and its corresponding i the cognitive approaches, provide flexible and robust solution for such systems, enabling new level of adaptability and re-configurability in the system by self-X capabilities.

In Light of this, the main objective of this paper, is to survey on concepts of Internet of Things based environments, and reviews the technologies, architectures/platforms, and trends in industries systems being cognitive and or smart. Afterward, we analyzed the research challenges and open issues and facilitate knowledge accumulation in efficiently in this field of Internet of Things (IoT) associated with industrial systems.

Keywords : Internet of Things (IoT), Cognitive Internet of Things(IoT), Paradigm, Smart Environment, Industry

I. INTRODUCTION

Internet of Things (IoT) is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects, where the real, digital and the virtual to create new applications/services and reach common goals, are converging to create smart environments that make energy, transport, cities and many other areas more intelligent [1]. The goal is to improve productivity within an operation and ultimately across the entire value chain by increasing visibility and access to contextual information connected to processes and products, to get the right information to the right people at the right time [2]. The development of IoT infrastructures will likely follow an incremental approach and expand from existing techniques [3]. A smart environment is a connected small world where sensor-enabled connected devices work collaboratively to make the lives of humans comfortable [4]. Several research efforts have been conducted to integrate IoT with smart environments. A connected small world established as a result of sensor-enabled, smart devices work collaboratively and make our lives comfortable, is defined as IoT-based smart environments, and such environments can be classified as : smart cities, smart homes, smart grid, smart buildings, smart transportation, smart health, and smart industry [5], figure 1, illustrates examples of smart environments. Consequently, smart industry, an instance of smart environments, represents the integration of three key productivity factors: automation, operations information, and advanced analytics. These factors link machines and equipment through open platforms and enable them to "think" – creating systems that are able to interact with one another, analyze data to predict failure, configure themselves and adapt to changes within the manufacturing process itself.

With researchers at the turn of the 21st century developing computers which operated at a higher rate of speed than the human brain did, Cognitive computing was reborn. Thanks to cognitive computing, most of industrial systems are becoming learning systems. Consequently, they integrate implanted data analytics, automated management and data-centric architectures in which the storage, memory, switching and processing are moving ever closer to the data. Their way of processing massive amounts of data is neither linear nor deterministic [5]. The integration of latest and enhanced tools such as, new cognitive approaches, with a cognitive /smart environment extends the capabilities of smart objects by enabling the user to monitor the environment from anywhere and anytime and to create Cognitive system. These tools can be integrated with different smart environments based on the application requirements. However, according the author in [2], many industry surveys, and most organizations aren't yet ready for Smart Manufacturing. Further, the authors argue that, for smart or cognitive manufacturing systems to be successful, technology alone is not sufficient but needs to be integrated in broader strategic design, planning and management practices. Besides, other conditions, like architectural paradigm or frameworks and models, are required for a successful manufacturing systems—be it smart or cognitive. Considering this reflection, one of the primary motivations of the paper to acquaint with recent paradigm called "CIoT", more or less, it deals without human intermediation, how general objects act as proxies, and interrelate with physical environment and/or social networks.

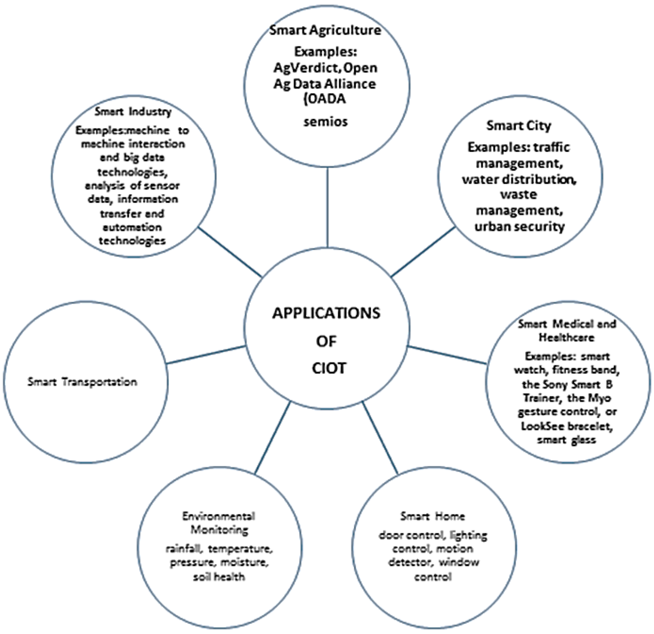

Figure 1: IoT-based smart environment.

To this end, at these instant, with the rapid popularity of IoT, and development of latest and enhanced tools, several research efforts have been conducted to empower and integrate IoT with smart environments. However, the research on CIoT is very limited, only connecting things is not enough, beyond that, general objects should have the capability to learn, think, and understand both physical and social worlds by themselves [6].

Keeping an eye on the industry cases, pervious literatures were systematically reviewed, to assess: what cognitive IoT based technology and architectural frameworks and, alternative approaches are existed, to achieve more convenient, justifiable, and irrepressible smart or cognitive industry are some of the aims of this survey paper.

So to bring a linear and vibrant effect, the paper was organized as follows: In section II: A literature survey on the proposed related works, particularly on the topics like research trends, smart and cognitive technology, architectural framework, were presented. In section III, the research challenges and open issues were also incorporated and tried to put future directions in the aforementioned research areas. Finally, the paper concludes with section IV.

II. LITERATURE SURVEY

In recent years, with rapid development in technologies, especially cognitive technologies, smart manufacturing are serving as a key driver of research, innovation, productivity, job creations and export growth, Now days, the development of IoT infrastructures, aspects of smart industry, will likely follow an incremental approach and expand from existing techniques [3], and a sufficient understanding of cognitive/ smart characteristics and requirements on factors such as cost, security, privacy, and risk is required before IoT will be widely accepted and deployed in such environments. Thus, the development to wards smart industry, can be support by the sources of new requirements, including national and international manufacturing initiatives, the Internet of Things initiative, standards development organization manufacturing programs, and to the emergence of sustainable manufacturing requirements [7]. However, the existing technologies, infrastructures and approaches are insufficient to fully enable cognitive/smart manufacturing, especially in the areas of cyber security, cloud-based manufacturing services, supply chain integration, and data analytics. Accordingly, many researchers have been working on designing and implementing various IoT-based manufacturing with cognitive services and on solving various technological and architectural problems associated with those service. According these authors, a special consideration should be given to SMS reference model and reference architecture, Internet of Things (IoT) reference architecture for manufacturing, manufacturing service models, Machine to machine communication, systems integration, Cloud Computing /Cloud manufacturing, manufacturing sustainability, manufacturing cyber security and so on. However, most of existing reference models in association with the technologies are not suitable for cognitive manufacturing applications that have severe safety and security requirements. Therefore, International cooperation efforts and a system-level perspective are needed to empower the capabilities to tackle the IoT related challenges [8]–[12]. Here after, the research trends towards the development smart manufacturing are presented.

From the pool of surveyed papers, the advances in IoT-based health care technologies and reviewed the state-of-the-art network architectures/platforms, applications, and industrial trends in IoT-based health care solutions, has surveyed in [13]. In addition, this paper analyzed distinct IoT security and privacy features. However, it was impossible to meet the requirements for cognitive services and, there are still many research challenges for IoT-based manufacturing use. Therefore, future efforts are needed to address these challenges and examine the characteristics of different IoT-based manufacturing to ensure a good fit of IoT devices in the IoT-based manufacturing environments [14]-[16]. Adequate efforts have been made concerning the designing and implementation of an integrated automation of systems. For instance, in [6], an integrated manufacturing automation system has been developed to deliver cost-effective and flexible operations. A new generation of robotic systems for future factories proposed [17]. A Service-oriented paradigm for automation was stated in [18]. A support tools based on QFD and FMEA for automation design presented in [19]. A modeling tools to evaluate performances of manufacturing system was developed in [20]. Some critical success factors for the integrated automation system has been summarized in [21]. Thus, latest technological changes brings an assortment of opportunities along with challenges in industry sector. Specially, IoT can play a vital in manufacturing companies by together with smart machines that can perform machine to machine interaction along with transforming data over internet. Industrial IoT include machine to machine interaction and big data technologies, analysis of sensor data, information transfer and automation technologies [22].

Appreciating the technologies in particular cognitive IoT, are at the fundamental for a smart/ cognitive manufacturing collectively enable effective integration of the increasingly complex components that make up modern manufacturing systems. Sustained advances in these technologies are desirable to empower significantly greater segment of manufacturing plants to take advantage of smart manufacturing concepts [23]. In addition, the authors, also tried to mention the essential Technologies for Smart/ cognitive Manufacturing such as networked sensors, data interoperability, multi-scale dynamic modeling and simulation, intelligent automation scalable and multi-level cyber security. Further, the authors in [24] had reviewed over 100 examples of organizations that have recently implemented or piloted an application of cognitive technologies, and have been aggressively experimenting with cognitive technologies in their own business and deploying multiple solutions based on them with great effect. These authors argued that, these examples spanned 17 industry sectors, including aerospace and defense, agriculture, automotive, banking, consumer products, health care, life sciences, media and entertainment, oil and gas, power and utilities, the public sector, real estate, retail, technology, and travel, hospitality, and leisure. Finally, they conclude that because cognitive technologies extend the power of information technology to tasks traditionally performed by humans, they have the potential to enable organizations to break prevailing tradeoffs between speed, cost, and quality.

Moreover, from the finding of several literatures, we found a generic IoT architecture which aims to provide a layered framework offers scalable mechanisms for registration, look-up and discovery of entities, as well as interoperability between objects, consisting of three layers: Virtual Object, Composite Virtual Object, and Service layer, has been presented in [25] by introducing an IoT daemon and Presenting these layers featured with automation, intelligence, and zero-configuration in each object guarantees scalability as well as interoperability in IoT environment. In order to deliver scalable services, [26] proposed their IoT Platform as a Service (PaaS) platform through virtual vertical service delivery. However, the current IoT Platform, being Platform as a Service (PaaS) or application platform as a Service (aPaaS), significantly lacks cognitive intelligence and cannot meet the application requirement. In addition, despite a three-layer, four or five-layer architectures and, the diversity IoT, which has been widely applied in the field of modern intelligent or cognitive service, the architectures of IoT were constructed utilizing traditional layered/hierarchic approaches. Thus, the architectures cannot meet the applications of CIoT, eg the classical manufacturing system architectural paradigm based on a hierarchical control mode, must be replaced [7]. Furthermore, though a plenty of work has been conducted toward smart manufacturing industries, most of them have not met the criteria to achieve these prerequisites for cognition/smartness. Besides, previous studies generally assumed static and prior planning and prediction for manufacturing processes, and therefore cannot accommodate dynamically changing environment [27].

Therefore, by effectively integrating the operational process of human cognition into the design of IoT and presenting detailed expositions of cognitive processing techniques that lie at the heart of CIoT [6]. Thus, an architectural framework should be build based on Ashton's visionary insights and enhance them by empower general objects to learn, think, and understand physical and social worlds by themselves. Introducing such framework for cognition into the engineering applications of IoT, a wide spectrum of tasks can be performed with minimal human intervention, plays a crucial role to realize the goals of developing a smart Manufacturing [28]. Consequently, to bridge the physical world (with objects, resources, etc.) and the social world (with human demand, social behavior, etc.), and enhance smart resource allocation, automatic network operation, and intelligent service provisioning scholars are continuously imagining to propose on framework of CIoT. For instance, within the research field of IoT, efforts have been made on a particular sub-area called cognitive IoT (CIoT) [29], which aims to incorporate cognitive capability into the conventional IoT framework to some extent [30]. The notion of a cognitive dynamic system (CDS) [31], [32] provides guidelines to build cognition into IoT in a systematic way. Adopting human cognition as the frame of reference, CDS has the following five pillars: perception–action cycle, memory, attention, intelligence, and language. Inspired by the effectiveness of human cognition and with a synthetic methodology learning-by-understanding. In response to the requirement of overcoming technological heterogeneity several work proposed cognitive technologies constitute an efficient approach for addressing the technological heterogeneity and obtaining context awareness, reliability and energy efficiency, a lot of framework was proposed. For instance, a new management mechanism for big data, that enables the processing of data and the extraction of valuable knowledge from it, can be offered by employing cloud computing with the CIoT, was presented in [33].In all these papers, the authors found the solutions and equilibrium status of the systems under consideration. In [29], an operational framework of CIoT paradigm, that could be applied to various applications scenarios such as smart home (ambient assisted living), smart office (easy meeting), smart city (smart transportation) or smart business (supply chain management) and having five fundamental cognitive tasks, sequentially: 1) perception-action cycle;2)massive data nalytics;3) semantic derivation and knowledge discovery;4)intelligent decision-making; 5) and on demand service provisioning, has been proposed . A generic cognitive management framework for the IoT also proposed in [34].

However the importance of it cannot be rated high enough due to various challenges and the manufacturing today are face different from the challenges in the past [35]. Thus, to explore the current challenges and open issues, from a perspective on Smart and/or digitalized and/or cognitive manufacturing, and to provide an elaboration on future the expectations, several papers have been reviewed. Therefore, new IoT-oriented cognitive functionality should be provided, which will be part of the service layer of the Future Internet [36].

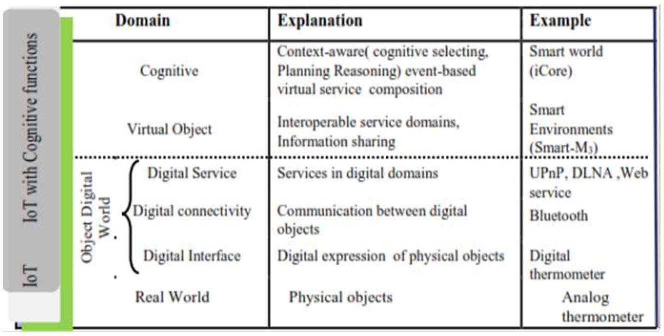

Figure 2: An architectural Framework for CIoT [34]

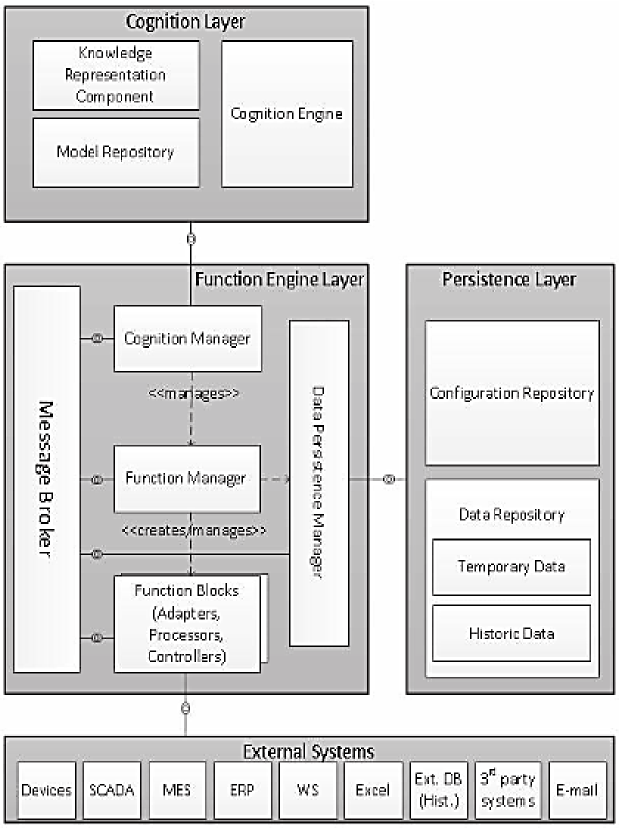

Figure 3: A cognitive architectural framework [36].

III. RESEARCH CHALLENGES AND OPEN ISSUES

Being recognized as evolving industry, many manufacturing systems are relay on technologies and technologies are converging to support and enable IoT applications towards cognitive Industry. Some of these technologies such as: IoT architecture, Networks technology, Software and algorithms and Security, trust, dependability and privacy, Interoperability, Standardization and so on are summarized in [1] and more [25]-[33]. However, many of the existing technologies, approach and techniques are available are not suitable for cognitive manufacturing applications that have severe safety and security requirements. Thus, to tackle the IoT related challenges and to empower their capabilities, further researchers' cooperation and efforts on a system-level perspective are required. Therefore, to provide a basis for the argumentation of cognitive capability, which is the appropriate tools and approaches for manufacturers to face those challenges (eg. machine learning and cognitive Technologies being the appropriate tools for manufacturers to face those challenges head on), under this section the recent challenges of CIoT and smart industry aspects, are reviewed.

According to [36], compared to buildings, businesses, or even entire industries, cities, a multitude of challenges to adopting infrastructure technology and the implementation of city-wide technology infrastructure, be it for smart or cognitive systems are presented and the challenges are categories as political, regulatory, economic, social, and technological. Although a lot of research efforts have been made on IoT technologies, to tackle challenges from the viewpoints of Technical Challenges, Standardization, Information Security and Privacy Protection categories are discussed in [3]. The Edge technologies, such as sensors and actuators, passive/active RFID tags, embedded systems, networking technologies are discussed, and challenges with respect to technology issues are among the challenges listed by the ISTAG (Information Society Technologies Advisory Group) and the European Commission are also presented. Further, the requirements for IoT-based systems (eg efficiency, scalability, secure, and reliability) must fulfilled before being deployed at a large scale and to meet at these requirements same time, the following challenges: 1) Scalability and technology integration 2) Performance, reliability and quality of service 3) Lack of global standards for device and service integration, security, privacy, architecture, and communications identified and described in [37], as well as the existing algorithms and mechanisms are unsatisfactory [38]. Further, according [39], with the technological evolution emerges a unified (Industrial) Internet of Things network, this evolution generates a huge field for exploitation, but on the other hand also increases complexity including new challenges and requirements demanding for new approaches in several issues.

Therefore, to increase the Internet of Things propagation with least cost and most efficiency and early bring the world towards the cognitive Internet of Things, we expect these companies and organizations to have cooperation together to dominate internet of things challenges [37]. Moreover, with aspect of CIoT, there are still several research challenges and open issues which are highlighted in [29].

Despite extensive research on future manufacturing and the forthcoming fourth industrial revolution (implying extensive smartness/digitalization), there is a lack of understanding regarding the specific changes that can be expected. Therefore, developing scenarios for future maintenance is needed to define long-term strategies for the realization of digitalized manufacturing. Clearly, Smart and/or digitalized manufacturing is a multi-faceted research problem that offer a broad palette of challenges for both society and academia; technological as well as social [40]. Some of the challenges and issues like: synchronization between different cloud vendors, Standardizing CC for IoT cloud-based services, balancing the differences in the infrastructure, unreliability in the security mechanisms, managing within different resources and components, are as the result the complexity of employing cloud computing with IoT [33]. In addition, d research issues which are structured in three main categories, namely technological, methodological, and business case research issues have identified by the authors in [41].

With the growing amounts of data, the rising complexity of systems, the emerged technological possibilities to analyses big data amounts, and the huge potential value in these data leads to the expectation that Big Data analysis will get more and more in the focus of many areas [39]. As noted by these authors, one challenge is the analysis of such systems that generate huge amounts of (continuously generated) data, potentially containing valuable information. Thus, Big Data analytics is arguably a major focus in the next round of smart manufacturing transformation, and could become a key basis of competitiveness, productivity growth, and innovation [42]. For IoT-enabled industries, although most challenges are interrelated to each other, can categorized into three areas: Hardware, software and data analytics, in particular, how they translate to challenges to data analytics identified in [43]. However, besides the features associated with big data, the above mentioned challenges in the hardware and software all present challenges and opportunities to new algorithm development. Despite its worthiness, as a big data analytics tool for IoT-based manufacturing, a statistics pattern analysis (SPA) based framework was proposed in [44]. Therefore, in the era of big data, there will be different modes of data analytics, such as streaming, batch, or mixed mode. In addition, more development is expected, in different forms of incremental modelling or iterative modelling or both to address large volume of streaming data for real-time statistical analysis and online monitoring [42]. Further, it is expected that different modes of data analytics will be used for different purposes. Therefore, to ensure providing good services that meet the future expectations for cognitive IoT based Manufacturing Systems enhancement of employing mechanisms is crucial [33].

Up on the extensive review of several studies, most of the researchers agree upon proposing challenges of manufacturing, are still available on a global level, such as adoption of advanced manufacturing technologies, growing importance of manufacturing of high value-added products, utilizing advanced knowledge, information management, and AI systems, sustainable manufacturing (processes) and products, agile and flexible enterprise capabilities and supply chains, innovation in products, services, and processes, close collaboration between industry and research to adopt new technologies and new manufacturing management paradigms, are the key challenges [35]. Accordingly, future manufacturing systems are expected to be robust and efficient and exhibit such as Self-X capabilities, remote diagnosis, real-time control, and predictability [45].

To meet these high expectations, a number of challenges, include but are not limited to: decision support systems to manage complex systems; standardization; security; broadband infrastructure; data quality; regulatory frameworks; and human-machine symbiosis also need to be addressed. Technological advancements needed are e.g. sensors, interoperability, data analytics, and additive manufacturing, and there are also business challenges such as privacy, investment limitations and coping with new business models, applications and/or services [45]-[48]. Ample studies of socio-ethical features of Smart and/or digitalised manufacturing [45], and social challenges highlighted in literature [49] are e.g. training and education, and work organization and design are also needed. From the collective literature, it is evident that Smart and/or digitalised manufacturing is a discontinuity that will bring a wide array of technological as well as social challenges.[45] claim that the potential of Smart and/or digitalised manufacturing is hard to underestimate, and that significant further research is needed in order to realize at least a portion of the partly exaggerated expectations.

Recently, cognitive or smart, well-defined architectures, data models or communication technologies as well as the integration of techniques in logical structures, play a crucial role. However, the heterogeneous techniques of different levels raise challenges in methodologies and approaches. To bridge the gap between techniques of different realms is a critical fundamental task for realizing cognitive or smart manufacturing systems. Likewise Manufacturers need practical guidance and most academic research is tangential to corporate needs. Academics push technological frontiers, from artificial intelligence to deep learning, without considering how they will be applied. Manufacturers want to know what types of data to sample, which sensors to use and where along the production line to install them. To illustrate this, let's see an instance; to improve product-material quality, which is challenging to attain, a manufacturer might want to monitor the performance of machinery as well as the structure of the product. Research is needed to determine the best configurations of sensors. For instance, in smart manufacturing innovation, the open issues which are in need of further research to be addressed are mentioned in [43], such as adopt strategies, improve data collection, use and sharing, design predictive models, study general predictive models ,connect factories and control processes. These features make industrial manufacturing applications different from light-weight and centralized monitoring cognitive-IoT based applications.

In continuation of current study, researchers anticipate to implement a set of use cases based on rough integration of cognitive technologies, cognitive architectures and models and/or techniques and approached to expose the opportunities for cognitive industry.

IV. CONCLUSION

Recently, with the rapid advancements in technology, manufacturing infrastructure and emerging empowering paradigm, cognitive internet of Things (CIoT)-the integration of cognition in to IoT, is evolving. CIoT is expected to be extensively applied to industrial systems, to achieve the development of Cognitive manufacturing on the globe. Due to this paradigm shift, most of the manufacturers have strong interest in deploying CIoT devices to develop manufacturing applications and services such as automated cognitive monitoring, cognitive control, cognitive management, and cognitive maintenance and so on. Moreover, researchers across the world have started to explore various technological and or methodological solutions to enhance manufacturing provision in a manner that complements existing services by mobilizing and empowering the potential of the IoT.

This survey paper reviews the relevant literatures on CIoT from the manufacturing perspective. This paper surveys the diverse background aspects of CIoT and manufacturing technologies, which integrates various smart devices equipped with cognitive sensing, cognitive identification, cognitive processing, cognitive communication, and cognitive networking capabilities.

In addition, extensive literatures are reviewed and detailed accomplishments are investigated, the paper provides the concepts of empowering and deploying IoT devices to develop the aforementioned cognitive manufacturing applications and services. For deeper insights into enabling cognitive technologies and research trends, the paper offers a broad view on the recent advancements on technologies- recently cognitive technologies and presents various proposed architectural frameworks, approaches and models that empowers and support access to the IoT backbone and facilitate cognitive manufacturing activities. Afterward, we analyzed the research challenges and future direction associated with CIoT and smart industrial systems.

In sum, the results of this survey are expected to be useful for researchers, engineers, manufacturing professionals, and policymakers working in the area of the CIoT and smart industry technologies.

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