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Cognitive IoT for Smart Environment: A survey on Enabling Technologies, Architectures, Approaches and Research Challenges

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Abstract: Novel paradigms based on cognitive IoT services are evolving. This paradigm shift is conveyed by integrating manufacturing assets with the latest and enhanced approach and technologies. Despite that today's industrial systems are facing various challenges. In line to this, the researchers believed that existing technologies and approach specifically, IoT, existing learning techniques and learning systems, lack enough cognitive the current IoT based systems significantly lacks cognitive intelligence this implies cannot fulfill the requirements for industrial services. and smart manufacturing developments.

In graceful of this, The foremost aim of our paper, is to survey advances in smart Environments background and reviews the concepts, technologies , architectures, design approaches and tools, and trends in Manufacturing 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 Cognitive Internet of Things (CIoT) associated with manufacturing systems.

Keywords: Cognitive Internet of Things (CIoT), Cognitive Approaches and Model, , Internet of Things (IoT), Intelligent Architecture, Smart Environments.

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1. INTRODUCTION

As it has been known, computer systems modeled developing after the human brain, which has the capability of natural language processing, learn from past, naturally cooperate with humans, and assist in making decisions, which is referred as Cognitive computing [1–3]. At the glance of this century and with reborn cognitive computing researchers investigated the speed of the developing computers outperformed at a better rate as compared to human brain. Besides, researchers began to use the modern term cognitive computing that integrates technology and biology in an attempt to reengineer the brain, that of the greatest efficient and effective computers on globe [4].

Thanks to cognitive computing, most of manufacturing 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 huge extents of facts is neither linear nor deterministic [4].

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.

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 to produce the cognitive capability. Having done a profound research on the divergences between provision offering and requirement, the researchers believed that current IoT lacks adequate intelligence which implies cannot achieve the expected increasing performance. IoT has been extensively applied in smart environments including smart buildings, smart cities, smart homes, smart transportation, smart health, and smart industry [5].

However, in the field of modern intelligent service, the current IoT based systems significantly lacks cognitive intelligence and cannot meet the industrial application requirement. Therefore, general objects in the IoT based systems need to acquire the ability to learn, to think, and to comprehend the physical and the social domains by themselves [6].

In line with this, due to swift development IoT, plenty innovative paradigm to enhance the existing smart environments or manufacturing services is evolving. This paradigm shift is brought by the rough guide of latest and enhanced smart/cognitive technologies and embedded intelligence at every level, a large number of enabling factors such as technologies, design and modeling paradigms and other support tools/ techniques are the crucial and fundamental component of the evolution. For example, to smart manufacturing especially in the areas of manufacturing services on cloud-based, data analytics, integration of supply chain, and cyber security and a hierarchical control model which is architectural paradigm based for the classical manufacturing system have been proposed in the few previous years [7].

An IoT is a paradigm which studies ubiquitous existence in the surroundings of a diversity of devices, where the tangible, virtual and the digital to create new applications/services and reach common goals, are joining to produce smart surroundings that make transport, cities, energy and a number of other areas more intelligent.

The crucial role of IoT is more noticeable in enabling access to devices and machines, which in manufacturing systems, were hidden in well-designed silos. Such advancement might permit the IoT or ICT to breach additional the smarter and or digitalized industrial systems. The IoT will connect the industrial unit to an entire innovative series of applications that runs everywhere the manufacturing. This might range starting from joining the place of work to the smart grid as well as distribution of facility in the production service and/ or permitting extra agility and flexibility inside the manufacturing organizations themselves [8].

Consequently, smart Manufacturing, an instance of smart environments, represents the integration of three key productivity factors: automation, operations information, and advanced analytics. Some of these factors such as equipment and machines over open platforms and which can enable them to “think” – generating organizations that could be able to cooperate among themselves, examine data to forecast catastrophe, organize and adapt themselves to fluctuations inside the industrial practice themself. The aim is to increase throughput in a process and eventually crosswise the complete price sequence by growing perceptibility and right to use of the contextual information connected to processes and products, to get the accurate information at the accurate time for the actual people.

However, many industry surveys, and most organizations aren’t yet prepared to enable Smart Industrial system [9]. Further, the researches claim 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.

Therefore, the architectural design of CIoT-based systems, like cognitive manufacturing systems, is concerned with architecture styles, networking and communication, cooperative data processing and security, smart things, services of the web with corresponding applications, business models with their corresponding process etc. for example, from the standpoint of technology, the architectural design of IoT should have to contemplate scalability, modularity, extensibility, and interoperability among heterogeneous devices.

In other way, according to industry analyst firm IDC, the installed base for the Internet of Things will grow to approximately 212 billion devices by 2020, a number that includes about thirty billion interconnected things or devices. IDC realizes this development motivated mainly by intelligent systems that will be mounted and gathering data - through consumer and enterprise of both applications [8], [10].

Keeping an eye on the manufacturing cases, pervious literatures were systematically reviewed, the various alternative means were investigated. This investigation, will support to assess: what cognitive IoT based technology and architectural frameworks and, alternative approaches are existed and why they are required, how cognitive capability were formed, to achieve more convenient, justifiable, and irrepressible smart or cognitive manufacturing 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 brief introduction on the core concepts was presented. Then as Section II, the background of IoT, CIOT as well as their integration with Smart environment and the like discussed. In section III, the paper reviewed, on the proposed related works, particularly on the topics like smart and cognitive technology, architectural framework, design approaches, models and the research trends in general. In section IV, 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 V.

2. BACKGROUND

All the way through the entire document, in order to focus on the possibilities and to have a common understanding, as matter-of-fact the terms Cognitive, smart and digitalized as well as industry and manufacturing were used interchangeably. In addition, CIoT refers to integration of cognition into IoT, all the characteristics for IoT are also considered same for CIoT too. Therefore, an assumption for the use of the terms CIoT and IoT may be following same fashion as of the terms should also be considered.

Although, the attribution on the preliminary use of IoT goes to, an expert on digital innovation, Kevin Ashton, later on, having a common idea that, the Internet as its first version was regarding data generated by people, and the second is regarding data generated by things, other groups also defined the term IoT [11].

Further, previously, bearing in mind the extensive experience and required technologies, from sensing objects, data aggregation and preprocessing, and communication system, to the object instantiation and finally service provision, an unambiguous definition of the "Internet of Things" generated, which was non-trivia. But, as global concept, it requires a common definition [8]. Here under, few of the some best operational definitions term are mentioned. Therefore, the IoT would be defined as:

1. *"IoT refers to vibrant overall network infrastructure with capabilities of self-configuration based on interoperable and standard communication protocols where virtual as well as physical "objects" have identities, virtual personalities, and physical attributes and use intelligent boundaries, and are faultlessly combined in the network" [8].*
2. *"IoT refers to an comprehensive and open network of smart devices which have the capability to bit information or data and resources, act and react as well as auto-organize, in aspect of conditions and environmental changes" [11].*

Moreover, enthused by the impression of connecting smart devices, IoT could be imagined as a future advancing technology like RFID technology which enables the automatic identification of the physical objects, which provides an opportunity to detect, recognize, and realize the real world by capturing data about the things (i.e. tagged objects using RFID) and support industries accomplish more effectiveness and responsibility [12], [13] [14].

Despite, the growing on the number objects or things and inter-connectivity among them, utmost the renowned features of IoT, a number of exciting services or applications are emerging. Thus, alternately, impressed by the use of ICT, makes the critical infrastructure components and services of a city administration, education systems, healthcare organizations, real estate, public safety, transportations systems and other utilities more responsive, cooperative and well-organized and such environments can be defined as smart environments [15], [16].

However, many of the existing smart environments exhausting IoT applications are still highly reliant on human beings for smart or cognition processing. Thus, as authors noted in [17], a special consideration, the operational process of human brain as the reference framework for cognition [18], must be taken. Moreover, it is vital to discourse the implication of the related term "cognition", it is more apt to refer to "cognition" as an "integrative field" since the study on "cognition" mixes several fields that are embedded in mathematics, physics, neuroscience, computer science and/ or engineering etc. [19]–[23], Similarly, CIoT is defined in [17].

Having said this, CIoT, is a recent paradigm, in which the physical as well as virtual things or objects are inter-connected and perform as proxies, interrelate one over another succeeding a perception-action cycle based on context-aware, by-building to learn from custom methodology by understanding environment, the physical and social networks, storing the acquired knowledge, and adjust to fluctuations or hesitations via mechanisms of resource-efficient decision-making, with least possible interventions of humans [19].

Note: In light to the discussion on the evolution of IoT technologies, the first generation IoT technologies already brought us the information which made a huge difference in accomplishing functioning competences. The second generation generates massive and widespread societies of objects that share information [24,113]. So to extend to the next level, industries need cognitive technologies that enable them to collect and assimilate facts from several sorts of sensors and other bases to explain and examine over that data [25]. Thus, cognitive computing and cognitive technologies could be considered as the 3rd stages in evolution of AI, starting from outdate AI to Artificial General Intelligence (AGI) to cognitive systems [4].

Therefore, researchers interested in computer intelligence became enthused and initiated to adopt the modern term cognitive computing that incorporates technology and human biology in an attempt to reengineer the brain, as the most efficient and effective computers on globe [26, 114]. And cognitive computing and cognitive technologies as well as their major asset are being able to accelerate the rate of learning to provision humans in their work. Eventually, cognitive systems will impact every industry and every enterprise. So, in this case, it is necessary to add the cognitive technologies to IoT portfolio such as machine learning, natural language processing and video, image and text analytics [27].

With major advances in cognitive science, there will be significantly increase human productivity through assisting, advising, and extending the capabilities of humans. For instance, some of the emerging cognitive engineering systems: like Cognitive Materials, Cognitive (smart) Cameras, Cognitive Production Systems and other cognitive infrastructures are found with detail description in [4], [115].

Furthermore, although the body of literature rapidly growing, applications, services and use of the term smart manufacturing and industry in academia still there is also absence of universally recognized accepting regarding what explains a manufacturing system to be ‘‘smart”. To have a concise standard definitions with the usage of Cognitive/smart manufacturing, a number of literature on smart and—more recently—cognitive, tried to define Smart manufacturing with respect to integration of technologies, approaches and related things. For instance, in [28], SM and other intelligent systems advanced industries [29-31] additive manufacturing [32], digital manufacturing [33], smart factory[34] and Industry 4.0[35] essentially are used on circumstance by few researchers.

In addition, in [36], the key points such as IoT, SoS, the service-oriented SoA, the autonomous units, big data analysis, complex event processing , adaptive and predictive control, or anticipating of composite situations, are few of ideas used for clarifying smart systems.

To this end, the term smart refers to the ability to autonomously obtain and apply knowledge, and the term environment refers to the surroundings. Therefore, smart environments are that are capable of obtaining knowledge and applying it to adapt according to its inhabitants' needs to ameliorate their experience of that environment [5]. Alternately, the adjective “smart” is applied to devices, in a similar fashion, when the adjective is used in the term “Smart Manufacturing” it means that manufacturing operations and systems are elevated to a novel level of openness, connectivity and intelligence [37] and defined as:

“Smart Manufacturing is the endeavor to design, deploy and manage enterprise manufacturing operations and systems that enable proactive management of the manufacturing enterprise through informed, timely (as close to real- time as possible), in- depth decision execution. Systems with Smart Manufacturing capabilities are realized through the application of advanced information, communication and manufacturing process technologies to create new and/or extend existing manufacturing system components that are then synergistically integrated to create new or extend existing manufacturing systems that possess the desired advanced automation, analysis and integration capabilities.”

Moreover, from the standpoints of engineering and technology, SM is an evolutionary step in computer-enabled production system control that pushes beyond “smart” technologies, retaining the intelligence and reasoning [7]. Thus, smart industry is the exaggerated use of advanced intelligent systems that allow fast industrialized of innovative yields, energetic reaction to invention request, and immediate optimization of industrial fabrication and resource sequence networks and attaches all phases of manufacturing, from ingestion of fresh resources to the distribution of completed yields to market [38].

Generally, we can deduce that SM means the consumption of implanted hardware and software technologies to improve throughput in the industry of goods or delivery and services [12] [39]. Conversely, since the complexity and heterogeneous environments of manufacturing systems, the cognitive capability and principles can integrate and configured with the context of their environmental applications. For example, self-organization principles can be applied to configuration by context sensing, especially concerning autonomous negotiation of interference management and possibly cognitive spectrum usage, by optimization of network structure and traffic and load distribution in the network, and in self-healing of networks [8]. Thus, how all this will be done in heterogeneous environments, without human interventions?

3. LITERATUREREVIEW

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. Further, the swift convergence of OT and IT technologies and organizations.

The vision whether called Industries 4.0, Connected Enterprise, Smart Operations, cognitive manufacturing is rapidly accelerating. The goals include a new level of productivity, safety, security, and optimization and the transformation of date into insightful and timely information, so that it gives decision makers across the enterprise new visibility into operations, improved opportunities to respond to market and business challenges and the ability to drive inefficiencies out of operations [37], [118-120].

In order to answer this question on “How and why the cognitive technologies are being used in today’s manufacturing? “, this section deals with related literatures for cognitive manufacturing systems and mainly focuses cognitive technologies, architectural Frameworks, models and trends to find a new research idea for Cognitive manufacturing systems and provide great scientific significance for automation system of most manufacturing factories and or industries today and the future.

A. Cognitive Technologies

Over decades, with impressive gains in computer vision, natural language processing, speech recognition, and robotics, among other areas, cognitive technologies have been evolving and businesses are taking a new look at them because some have improved dramatically.

Thanks to 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 [38]. 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 [50] 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. In addition, 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.

To this end, the applications of cognitive technologies fall into three main categories: product, process, or insight. Product applications embed the technology in a product or service to provide end-customer benefits. Process applications embed the technology in an organization’s workflow to automate or improve operations. And insight applications use cognitive technologies specifically advanced analytical capabilities such as machine learning to uncover insights that can inform operational and strategic decisions across an organization [8].

B. Architectural Frameworks

As the finding of several literatures, we found a generic IoT architecture, aims to provide a layered framework that 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 [41] 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, [42] proposed their IoTPaaS platform through virtual vertical service delivery. However, the current IoT 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 [43], [6].

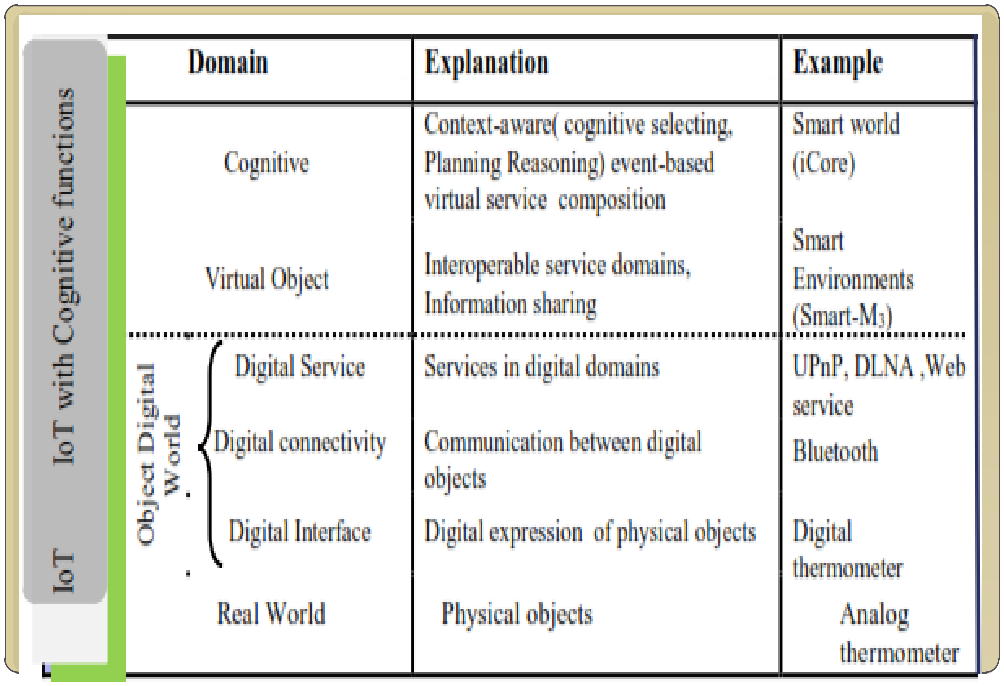
Therefore, by effectively integrating the operational process of human cognition into the design of IoT and presenting detailed expositions of cognitive processing techniques that lie at the heart of CIoT, an architectural framework should be build based on Ashton’s visionary insights and enhance them 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 [24]. According them, 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 [121-123], 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) [44], inspired by the effectiveness of human cognition and with a synthetic methodology learning-by-understanding which aims to incorporate cognitive capability into the conventional IoT framework to some extent [45]. The notion of a cognitive dynamic system (CDS) [46], [47] 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. 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.

In [17], 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 [48]. Therefore, new IoT-oriented cognitive functionality will be provided, which will be part of the service layer of the Future Internet. Fig. 1 illustrates the transition from legacy to cognitive IoT by using modest objects as examples.



		Domain	Explanation	Example
IoT with Cognitive functions		Cognitive	Context-aware(cognitive selecting, Planning Reasoning) event-based virtual service composition	Smart world (iCore)
		Virtual Object	Interoperable service domains, Information sharing	Smart Environments (Smart-M$_3$)
IoT	Object Digital World	Digital Service	Services in digital domains	UPnP, DLNA ,Web service
		Digital connectivity	Communication between digital objects	Bluetooth
		Digital Interface	Digital expression of physical objects	Digital thermometer
		Real World	Physical objects	Analog thermometer

Fig.1: An architectural Framework for CIoT [48]

Similarly, taking into account information and knowledge on the context of the operations as well as policies and including the generation of the context itself, a cognitive framework have been proposed in [48] and with the consideration to play a crucial role of empowering the ability of the IoT to adopt dynamically with the conditions of the physical objects of our surroundings, where cognition mainly refers to the autonomic selection of the most relevant objects for the given application and a cognitive management framework, that empowers the ability of the IoT to dynamically select its behavior through self-management/awareness functionality was proposed in [49].

Although, research scholars have barely provided a holistic framework that integrates information and processes together. However, to enable for optimization during the manufacturing processes, together with techniques and promising tool have to be considered to offer “smartness /cognitive” capabilities to empower more the manufacturing activities.

Recently, in several studies, to empower the current IoT with a “brain” for high-level intelligence practical needs impels us to develop a new paradigm, named cognitive Internet of Things (CIoT) [17], are evolving. For instance, to address Cognitive Manufacturing with truly biological-inspired rationale under open service oriented architecture have been proposed in [50]. Further, a general and promising tool, as in in [43], that could be employed to predict and optimize manufacturing processes through continuous learning for a complex manufacturing industrial system and machine learning techniques which offer “smartness / cognition”, should have to be considered.

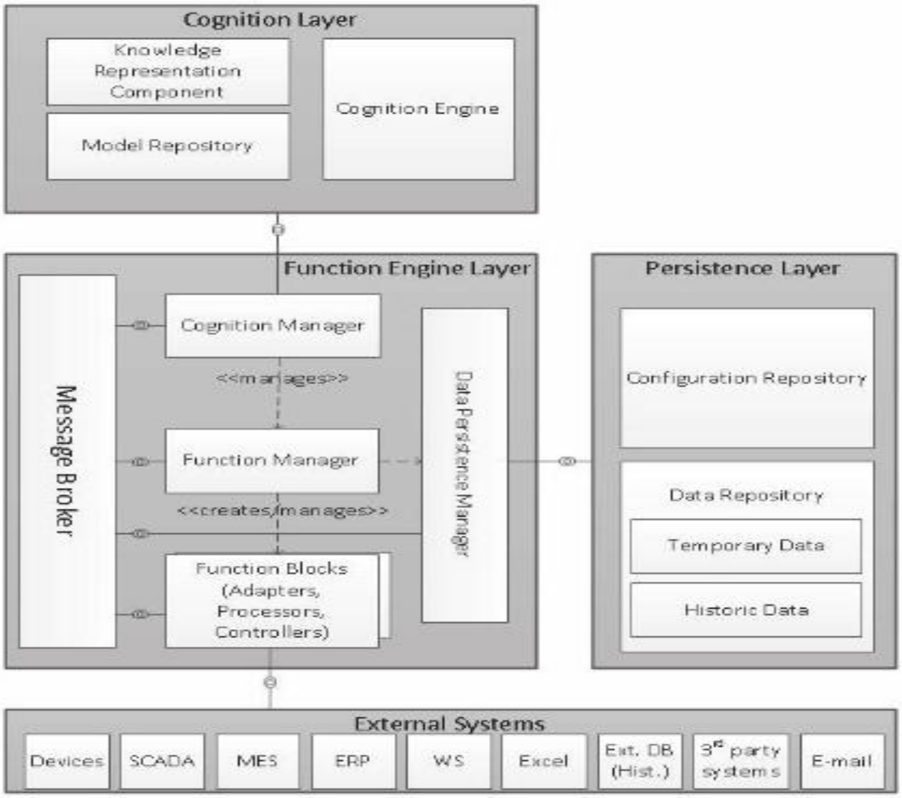


Fig. 2: A cognitive architectural framework [50]

However, few of these studies have been proposed a systematic process that guides the users to introduce machine learning into different manufacturing systems under realistic condition [6]. The architectures which allow control loops, decision-making, self-learning, reconfiguration and self-optimization on higher level of such systems and targeted to overcome enormous complexity and diversity of such system [50], as shown in fig. 2, are very limited.

C. Design approaches and other tools

In contrast to conventional machinery monitoring, smart manufacturing processes monitoring should covers a part with cognitive monitoring and manual working processes monitoring. Thus, a cognitive design model that creates compatibility between parts and products on working area to double check workers attentions and to give assistance to workers for avoiding mistakes plays a crucial role [51], [124-126].

Furthermore, the superglue relation among various platforms such as data and measurement platform, modeling and orchestration platform, and the control platform can be realized via cognitive models, representation of the real world things. There are multiple abstraction levels of models of the real world. Here after, few of the proposed models in the CIoT domain have been reviewed.

From the pool of proposed models, a novel Digital Object Memory (DOMe) based model in automated surface roughness monitoring and data storage in turning is proposed in [51]. This model allows automated interaction between work piece (WP) and machine tool using RFID based smart environment. To support for smart industry decision makers to evaluate its employee’s efficiently based upon their performance rather than relying on personal views of their higher authorities, a game based model was proposed in [52]. Moreover , diverse models are used by several authors [17], [53]-[55], for decision making such as spatial game models for large- scale CIoT, consensus model, agent based model, Bayesian decision making model, neural networks, game model respectively, and many more [59-60].

However, due to global information exchange among all players is not possible in large-scale CIoT, the spatially distribution of players, remote information exchange in the interactive range is infeasible and spatial game is generally hard to analyze [17]. As, one promising approach introducing local cooperation into spatial game, it was shown that local cooperation leads to near-optimal optimization [61]. Thus, local information exchange in the interactive range is feasible, the global information exchange among all players is still not possible in large-scale CIoT. Therefore, game based and the related models have less importance for Cognitive Manufacturing systems.

In order, sympathetic the complexity of systems-of-systems, predicting their trajectory and controlling their actual evolution, designing system models of distinct natural, engineered, people, and business worlds, based on a cognitive representation approaches, are essential. Furthermore, cognitive representation for our emerging service and analytics can create accurate decision support capabilities when reversing through uncertain environments whose conditions are not known a priori [122]. IoT combined with cognition modeling is referred to as Cognitive IoT (CIoT) is important [62], [63].

The rapid adoption of Internet of Things (IoT) together with unprecedented bandwidths and computational power in instrumentation devices have already produced ground-breaking real- time or near real-time visibility and analysis across a broad spectrum of system environments[64]-[68]. These capabilities enable instant access and transfer of information about a system or device in both natural and engineered systems as well as in consumer and manufacturing environments [69], [127-129].

In addition, with the new developments in certain domains like mathematics and computer science (e.g. statistical learning) and availability of easy-to-use, often freely available (software) tools offer great potential to transform the manufacturing domain and their grasp on the increased manufacturing data repositories sustainably [70].

In general, the design model of a system that incorporates various levels such as, the conceptual, functional, structural levels and these levels support to improve outcomes while maintaining manageable complexity and uncertainty, is crucial. Furthermore, the superglue relation among various platforms such as data and measurement platform, modeling and orchestration platform, and the control platform can be realized via cognitive models, representation of the real world things.

Therefore, in harmony to our understanding, CIoT could be viewed as the current IoT integrated with cognitive and cooperative techniques/mechanisms to promote performance and achieve intelligence, to improve the production process and enhance the monitoring system, manufacturing factories should have to have an adequate automation and interconnected data to support smart manufacturing. Due to this fact, the cognitive process model made up of a three-layer cognitive ring was proposed in [19].

Based on a combination of a rule-based system and a learning system to achieve smartness and to represent the best known current states of the manufacturing system a computational reasoning and learning system to facilitate cognitive/smart manufacturing under realistic conditions described by three dimensions, i.e., the “three I’s in one” model with interconnected data, intelligent information and integrated automation, also proposed by the authors in [6]. Their approach made an attempt to explain how to realize cognitive/smart manufacturing from a more formal methodological view point to gain data, transfer data, process data into information, applied information to production, get feedback and update itself under realistic manufacturing conditions.

Therefore, in harmony with manufacturing standpoint, the authors of this article, would like to remark that, to achieve smartness/ cognition, suitable approaches need to be developed based on a learning system to represent the best known current states of the manufacturing system, machine learning is an appropriate and promising tool to tackle with today’s and future challenges. Furthermore, to realize smart manufacturing from a more formal methodological view point areas of machine learning and propose an overall structuring and to provide with a high-level understanding of certain methods with respect to manufacturing application.

However, due to the field of machine learning is very diverse and many different algorithms, theories, and methods are available. For many manufacturing practitioners, this represents a barrier regarding the adoption of these powerful tools and thus may hinder the utilization of the vast amounts of data generated be cognitive IoT devices increasingly being available [70], [129-131].

D. Research trends

Now days, the development of IoT infrastructures, aspects of manufacturing, will likely follow an incremental approach and expand from existing techniques [71], 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 manufacturing, 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 is 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 [72]–[76]. 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 [77]. 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 [78]-[80].

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 [81]. Service-oriented paradigms for automation was stated in [82]. A support tools based on QFD and FMEA for automation design presented in [83]. A modeling tools to evaluate performances of manufacturing system was developed in [84]. Some critical success factors for the integrated automation system has been summarized in [85].

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 [14].

In view of that, the literatures including [86] implied the current understanding of Smart and/or digitalized manufacturing is, at its staple, mainly about technology [87]-[95]. In the same vein, the literature in [86], highlighted very striving opportunities of Smart and/or digitalized manufacturing. For example, data is one of the enabler for productivity gains, innovation and economic growth [95] and it is upstretched as the great resource of the next industrial and manufacturing era [96], and further, its value is leveraged by horizontal and vertical integration of IT systems [86], [89], [90]. However, it is at the same time clear that the technology, especially cognitive, in manufacturing factories of the future inflict social challenges. For instance, manufacturing companies must develop a staff with new and higher levels of competence [96] by attracting new capacity [86], [87] improving the existing staff in parallel [92]. This, in turn, creates a need for continuous self-upgrading via training and education [92], put burden on education systems [97] and entail closer teamwork between industry, manufacturing and academia [89].

Manufacturing is a very recognized industry, so at present, Smart/ digitalized and/or cognitive manufacturing has become a top priority for research centers, universities, and companies. Despite differences in competence, degrees, age, or culture, considering manufacturing a vital part in the future of effort means developing work environments that are technically efficient and socially sustainable: creative, flexible, safe, and welcoming to personal and professional development [92], [94], [96].

To manage issues with legislation, liability, and privacy of industrial or manufacturing data, re-inventing legacy systems is also essential [86], [90], [93]. By impelling new market players, services, and business models, the business environment will also unsettle Smart and/or digitalized manufacturing [86]-[96]. Accordingly, numerous initiatives to renovation the manufacturing sector were started. Instances are the US through 'Executive Actions to Strengthen Advanced Manufacturing in America' [102] and the European Union with their 'Factories of the Future' [103] initiative.

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 [70]. 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.

4. RESEARCH CHALLENGES AND OPEN ISSUES

Being recognized as evolving industry, many manufacturing are systems relay on technologies and technologies are converging to support and enable IoT applications towards cognitive MS. 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 [8]. However the relevance of it cannot be rated high enough due to various challenges and the challenges manufacturing faces today are different from the challenges in the past [70].

Many existing technologies, approach and techniques are available for consumer use, but are not suitable for cognitive manufacturing applications that have severe safety and security requirements. International cooperation efforts and a system-level perspective are needed to empower the capabilities to tackle the IoT related challenges [72]–[76].

Recent MS are facing with the challenges that are far apart from the previous ones. 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 manufacturing aspects, are reviewed.

According to [50], 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 [71].

In [27], the Edge technologies, such as sensors and actuators, passive/active RFID tags, embedded systems, networking technologies have been discussed, and challenges with respect to technology issues are also 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 [104], as well as the existing algorithms and mechanisms are unsatisfactory [106]. According [36], 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 [104]. Moreover, with aspect of CIoT, there are still several research challenges and open issues. Some of which are highlighted in the extensive work of [17].

In practical CIoT applications, it is much more challenging to process the obtained massive sensing data that can be of mixed characteristics, including heterogeneity, high dimensionality, nonlinear reparability, etc. and for different applications in large-scale CIoT applications, the game models and the multi-agent learning algorithms should be carefully designed. In particular, the local interaction and the uncertain, dynamic, and incomplete information constraints should be taking into account for decision-making.

In most existing multi-agent learning algorithms, the players update their strategies based on the history action-payoff information. This procedure may take long time to converge since the players need to explore all the possible selections. In CIoT, some new knowledge-assisted learning technologies should be developed to increase the converging speed and achieve better performance. Though, generic approaches in CIoT research mainly focus on abstracting common techniques involved in various applications.

However, generic approaches cannot be directly used for each specific situation. To apply the generic approaches for specific situations, more practical constraints should be further considered.
Developing effective semantic technologies and knowledge discovery techniques that are more suitable for CIoT applications is still a fundamental task. Thus, more attention should be focused on building the bridge from theory to practice. For example, how and where might the theoretical studies in CIoT research actually be applied?

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 for maintenance organizations. Therefore, developing scenarios for future maintenance is needed to define long-term strategies for the realization of digitalised manufacturing. Clearly, Smart and/or digitalised manufacturing is a multi-faceted research problem that offer a broad palette of challenges for both society and academia; technological as well as social [86]. 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 CIoT.

In addition, the authors [108], identified research issues which are structured in three main categories, namely technological, methodological, and business case research issues. With the growing amounts of data, the rising complexity of systems, the emerged technological possibilities to analyse 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. Smart Manufacturing is only one of them. Similar to above general challenges, in smart manufacturing systems also other challenges occur [36] 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.

Big Data analytics is also arguably a major focus in the next round of smart manufacturing transformation, and could become a key basis of competitiveness, productivity growth, and innovation [109]. For IoT-enabled manufacturing, from the development and initial testing of the IoT-enabled MTT system, challenges, although most are interrelated to each other, categorized into three areas: Hardware, software and data analytics, in particular, how they translate to challenges to data analytics identified in [110].

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 [111]. 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 modeling or iterative modeling or both to address large volume of streaming data for real-time statistical analysis and online monitoring [109]. 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 [14].

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 [70].

Accordingly, future manufacturing systems are expected to be robust and efficient and exhibit e.g. Self-X capabilities, remote diagnosis, real-time control, and predictability [99]. 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 [98-101].

Ample studies of socio-ethical features of Smart and/or digitalised manufacturing [99], and social challenges highlighted in literature [101] 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.[99] 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.

Therefore, to address with the issues in the future, it is remarkable to consider not only the characteristics Opportunities and Challenges that distinguish smart/digital manufacturing applications but also other CIoT scenarios, including: powerful machines and reliable network connection, machines make decisions and fulfill operations locally, machines generate data, and consume data from peers and interactive and high throughput data communication, as noted and found with detailed summary in [112].

Further, to innovate the manufacturing industry, 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 [110], 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 manufacturing.

5. CONCLUSIONS

Recently, with the rapid advancements in technology, manufacturing infrastructure and emerging empowering paradigm, cognitive internet of Things (CIoT)-the integration of cognition in toIoT, is evolving. CIoT is expected to be extensively applied to manufacturing 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 counterparts the prevailing services by organizing and empowering the potential of the IoT.

Our paper reviewed 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 manufacturing systems.

Finally, unlike other survey papers, the key role of this review paper, we expect that the presented article is offered as a sheer step in a potentially fruitful research direction in this field. In addition, we are confidence on this article, with interdisciplinary perceptions, will encourage more securities in the research and expansion of CIoT, to enable intelligent allocation of resource, automation of network setup, and intelligent service provisioning, in cognitive manufacturing 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 manufacturing technologies.

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