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THE COGNITIVE INTERNET OF THINGS

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Abstract: It is not difficult to find that the structure of the Internet is getting more and more similar to brain structure. The structure of the Internet from the perspective of neurology is very similar to the human brain, specifically the Internet virtual brain. When cognitive computing is applied to the Internet of Things, the result is what we call Cognitive IoT, which we define as systems that infuse intelligence into and learn from the physical world. This paper explores the general relation between artificial intelligence and the Internet of Things, cloud computing, big data and the Industrial Internet from the perspective of cognitivism.

Key words: virtual brain, AI, IoT, CIoT, cognitive, cloud computing, big data

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Introduction

All objects in the world can actively exchange information through the Internet. This is achieved by interconnections between objects, omnipresent networks and omnipresent computing anytime and anywhere. The communication field emphasizes the transmission of information, while the computer realm emphasizes the utilization of information. "A mass of new applications and features of the Internet have emerged in the past 20 years. For example, a printer or copying machine is remotely controlled; doctors perform operations through the remote network; Chinese water conservancy authorities place sensors in the soil, rivers and air so that the temperature, humidity, wind speed could be transmitted to the information processing center timely through the Internet, thus a report is formed, providing reference for decision-making in flood and drought control; Google launched the 'Street View' service, with which, multi-lens cameras may be installed in a city so that the Internet users can enjoy the real-time scenes in Denver, Las Vegas, Miami, New York and San Francisco and other cities. It is not difficult to find that the structure of Internet is getting more and more similar to the brain structur" (read more Feng Liu, *Analysis of the Relation between Artificial Intelligence and the Internet from the Perspective of Brain Science* ITQM 2017). These new Internet phenomena can be taken as the emerging motor nervous system, the somatosensory nervous system and the visual nervous system respectively. The structure of the Internet from the perspective of neurology is highly similar to the human brain, namely the Internet virtual brain. The Internet of Thing is the beginning of the sensory nervous system of the Internet brain. On this basis we can reanalyze the Internet of Things, cloud computing, big data, artificial intelligence (deep learning), the industrial Internet and virtual reality.

Cloud computing

Cloud computing is the emerging central nervous system of the Internet brain. After IBM and Google announced their cooperation in the field of cloud computing in October 2007, cloud computing has quickly become a hot issue in industrial and academic research [1]. The birth of cloud computing has historical roots. With the development of the Internet, the demand for Internet's data storage capacity of emerging applications has started to grow, and the Internet business has begun to expand as well. Therefore, the hardware and software maintenance costs of the Internet enterprises continue to increase which poses a heavy burden for most of them [1]. At the same time, the Internet super-large enterprises such as Google, IBM and Amazon have a lot of spare hardware and software resources that are not fully utilized [1]. In this case, it has become necessary for the Internet to reform from constructing the hardware and software separately to sharing the centralized cloud computing. In the Internet virtual brain architecture, the central nervous system of the Internet virtual brain is the Internet's core hardware layer, which binds the information layer to provide support and services for the virtual neural systems of the Internet. From the point of view of the definition, cloud computing has similar characteristics to the central nervous system of the Internet virtual brain. In an ideal situation, the sensor of Internet of Things or the Internet user interacts with cloud computing through the network lines and computer terminals, provides data to the cloud computing and accepts the services.

Big data

Big data is the basis of Internet brain information. With the rise of technologies such as blogs, social networks, cloud computing, the Internet of Things, and the Industrial Internet, the data and information on the Internet are growing and accumulating at an unprecedented rate. An internet users' interaction with another, information from enterprises and governments, and real time information from the Internet of Things and sensors generate enormous amounts of structured and unstructured data at all times. Such data is scattered throughout the Internet network system at a huge volume. The data contains very valuable information on the economy, science and technology etc. This is namely the background for the rise of Internet data [2].

Industry 5.0, Industrial Internet

Industry 5.0, Industrial Internet, unmanned aerial vehicles, intelligent driving and 3D are essentially the emerging Internet motor nervous system. The Internet's central nervous system, namely the software system in cloud computing, controls the production equipment of industrial enterprises, household appliances, and office equipment. It causes mechanical equipment such as intelligence, 3D printing and wireless sensors to become the tools for the Internet brain to reform the world. At the same time, these intelligent creations and intelligent equipment also return data to the Internet brain so that the Internet central nervous system performs decision-making based on such data. In the entire process, the technologies and applications such as Industry 5.0, the Industrial Internet, unmanned aerial vehicles, intelligent driving, 3D printing are just the products from the development and emerging Internet's motor nervous system.

Virtual and Augmented reality

Virtual reality (VR) is a computer-generated scenario that simulates experience through senses and perception. The immersive environment can be similar to the real world or it can be imaginary, creating an experience not possible in ordinary physical reality. Augmented reality systems may also be considered a form of VR that layer virtual information over a live camera feed into a headset or through a smartphone or tablet device giving the user the ability to view three-dimensional images.

Augmented reality (AR) is a direct or indirect live view of a physical, real-world environment whose elements are "augmented" by computer-generated perceptual information, ideally across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory [3]. The overlaid sensory information can be constructive (i.e. additive to the natural environment) or destructive (i.e. masking the natural environment), and it is spatially registered with the physical world such that it is perceived as an immersive aspect of the real environment [6]. In this way, Augmented reality alters one's current perception of a real world environment, whereas virtual reality replaces the real world environment with a simulated one [4, 5]. Augmented reality is related to two largely synonymous terms: mixed reality and computer-mediated reality.

Mixed reality (MR) – sometimes referred to as hybrid reality – is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. Mixed reality is an overlay of synthetic content on the real world that is anchored to and interacts with the real world – picture surgeons overlaying virtual ultrasound images on their patient while performing an operation [4, 5]. The key characteristic of MR is that the synthetic content and the real-world content are able to react to each other in real time.

Hardware associated with mixed reality includes Microsoft's HoloLens, which is set to be vital in MR – although Microsoft has dodged the AR/MR debate by introducing yet another term: "holographic computing". Microsoft has just announced a HoloLens emulator for developers, so you can make applications for the new tech [3–6]. The popularization and extensive use of IoT will generate more and more data that will provide important information sources for the realization of cognitive computing. In turn, as a new type of computing mode, cognitive computing[1] will provide a means of practice with higher and better energy efficiency for data perception and collection in IoT.

The Evolution of Cognitive Computing

Cognitive Science[2] has emerged. It is an interdisciplinary subject that studies the circulation and treatment of information in the human brain. Cognitive scientists explore the mental ability of human beings through observation on aspects such as language, perception, memory, attention, reasoning and emotion [9]. The cognitive process of human beings is mainly reflected in the following two stages. Firstly, people become aware of ambient physical environments through their own perceptive sense organs such as skin, eyes and ears, etc., by which the external information is obtained as inputs. Secondly, the input is transmitted to brain through nerves for complicated processing such as storage, analysis and learning. The processing results are fed back

[1] This definition of cognitive computing was developed in mid-2014 by a cross-disciplinary group of experts. Cognitive computing (CC) describes technology platforms that, broadly speaking, are based on the scientific disciplines of artificial intelligence and signal processing. These platforms encompass machine learning, reasoning, natural language processing, speech recognition and vision (object recognition), human–computer interaction, dialog and narrative generation, among other technologies [7].

[2] Cognitive Science is the interdisciplinary study of cognition in humans, animals, and machines. It encompasses the traditional disciplines of psychology, computer science, neuroscience, anthropology, linguistics and philosophy. The cognitive sciences began as an intellectual movement in the 1950s and was often referred to as the cognitive revolution [8].

to various body parts through nervous system, and then each part produces an appropriate behavioral response [9]. Thus, a complete closed loop that covers decision-making and action is formed. Therefore, when a newborn recognizes and understands the world, constant communication with the outer world is required to obtain various information on external environments. In the meantime, he or she gradually establishes his or her own cognitive system by using the obtained information and feedback. Since the cognitive system is extremely complex, it is essential to use the tools and the methods from various subjects, in order to conduct multi-dimensional [10], all-around and in-depth studies for a better understanding of the cognitive system. Therefore, cognitive science crosses many subjects and research fields such as linguistics, psychology, AI, philosophy, neuroscience and anthropology. In a manner of speaking, the achievements obtained by researchers in the field of cognitive science up to now are closely related to interdisciplinary research methods.

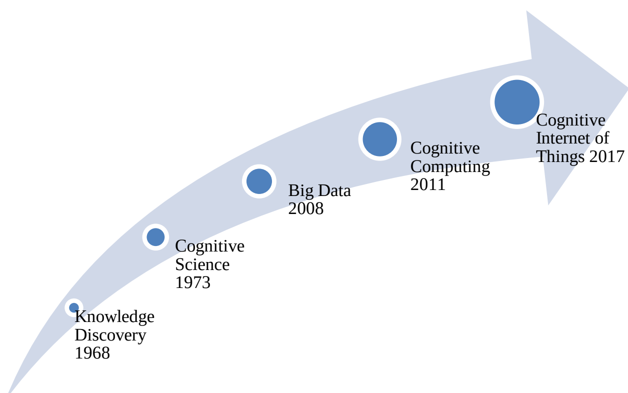

Fig. 1: Cognitive Internet of Things Evolution.

Fig. 1 shows the evolution process of the cognitive Internet of Things. Big data analysis and cognitive computing are two different technologies that are derived from data science. As for big data analysis, it is emphasized that the data processed should be characterized by the "5V" features of big data [11]. Cognitive computing focuses more on breakthrough in processing methods. In cognitive computing, the data processed are not necessarily big data. Just like the human brain, a limited memory does not affect the cognition of image information. Actually, the image processing by the human brain is extremely efficient. Cognitive computing tends to develop algorithms by utilizing the theories in cognitive science. Finally, it enables a machine to possess a certain degree of brain-like cognitive intelligence [12]. Brain-like computing aims to enable computers to understand and cognize the objective world from the perspective of human thinking. In order to understand the needs of human beings, it is critical to strengthen the cognition of machine through cognitive computing [13]. Thus, the intelligence and decision-making ability of machines need to be improved. Especially with respect to problems that involve complicated emotions and reasoning, cognitive computing will far exceed traditional machine learning. When cognitive computing is embedded into IoT, the smart IoT system may assist human beings in decision-making and provide critical suggestions [14]. Cognitive technologies can also be integrated with information communication system in order to spawn novel cognitive radio networks [15]. For instance, in [16]. Tian et al., propose the first application of multiple-input-multiple-output (MIMO) transmissions based on robust optimized cognitive radio to vehicular networks to enhance the performance of vehicular networks. If the data processed by cognitive computing are big data, then both cognitive computing and big data analysis are used at the same time.

Why Cognitive IoT?

In recent years, with the rapid development in computer software and hardware technologies as well as big data and artificial intelligence (AI), cognitive computing has received considerable attention in both academia and industry. In academia, the IEEE Technical Activity for cognitive computing defines it as "an interdisciplinary research and application field", which "uses methods from psychology, biology, signal processing, physics, information theory, mathematics, and statistics" in an attempt to construct "machines that will have reasoning abilities analogous to a human brain" [14]. In the industry, IBM developed the cognitive system, i.e., Waston, which could process and reason about natural language and learn from documents without supervision. Those works focus on strong AI, and the intelligence of these systems is based on the diverse data provided by cyberspace [14, 17].

At its heart, the Internet of Things is a data challenge. The traditional approach to programmable computing – in which data is shepherded through a series of predetermined, if/then processes to arrive at outcomes – simply cannot process the degree and kind of data needed to fulfill the true promise of IoT. Programmable systems thrive on prescribed scenarios using predictable data. And this rigidity limits their usefulness in addressing many aspects of a complex, fast-paced world, where the value of data decreases exponentially every second it goes unused. When cognitive computing is applied to the Internet of Things, the result is what we call Cognitive IoT (see Fig. 2), which we define as systems that infuse intelligence into and learn from the physical world.

But it is not just the input that sets Cognitive IoT apart. In addition to generating answers to numerical problems, cognitive systems can present unbiased hypotheses,

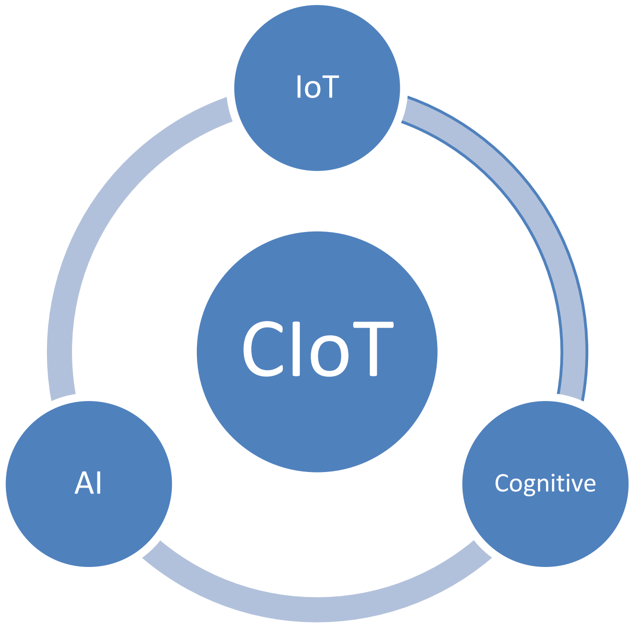

Fig. 1: Cognitive Internet of Things.

reasoned arguments, and recommendations. They understand your goals and can integrate and analyze the relevant data to help you achieve those goals. However, modern cognitive computing still falls short of realizing human-like intelligence. Specifically, current technological advances in cognitive computing face the following challenges.

Most of the existing industrialized AI systems are still preliminary AI-based applications. Furthermore, a lot of applications based on neural network and deep-learning framework, such as Smart City [18–21], Smart Health-care [22–24], Smart Home [25–27] and Smart Transportation [28, 29], have not yet extended sufficiently to the realm of spirit and do not focus on human-centered intrinsic information such as emotions and mentality. Without continuous provisioning of big data, it is difficult to sustain the discovery of knowledge for the improvement of machine intelligence. Furthermore, the human expectation of the ability of machine is increasing. Therefore, it is significantly important whether the development of AI in a later period will be able to break through the limitation of data.

The system architecture of Cognitive IoT

The brain-like Internet architecture provides new insights for the establishment of new artificial intelligence systems. The Internet born in the last century has had more and more of an impact on human society. Various signs indicate that the Internet has a close relation with brain science. From 2005, the research has suggested that the Internet will evolve toward the state highly similar to the human brain [8]. It will not only have its own visual, auditory, tactile, motor nervous systems, but it will also have its own memory nervous system, central nervous system and autonomic nervous system. On the other hand, the human brain has evolved all the Internet functions at least tens of thousands of years ago, and the continuously-developing Internet will help neurologists to reveal the secret of the brain. This research inspires us to explore the possibility of building anartificial intelligence system model simulating the Internet brain in a supercomputer using Internet functions and architecture Meanwhile, there needs to be an investigation into the possiblityof increasing or reducing relevant functions and architectures in the building process according to the latest developments of the Internet. The software system of this model can also be integrated in the chip.

Fig. 3 shows the system architecture of cognitive computing. With the support of underlying technologies such as 5G network [30], robotics and deep learning along with IoT/cloud infrastructures, tasks involving human-machine interaction, voice recognition and computer vision will be implemented on a large scale. The upper applications supported can be medical supervision, cognitive healthcare, smart city, smart transportation and scientific experiments. Additionally, each layer in the system architecture is accompanied by corresponding technological challenges and system requirements. Therefore, the relevance between cognitive computing and each layer is studied and discussed in detail in this paper.

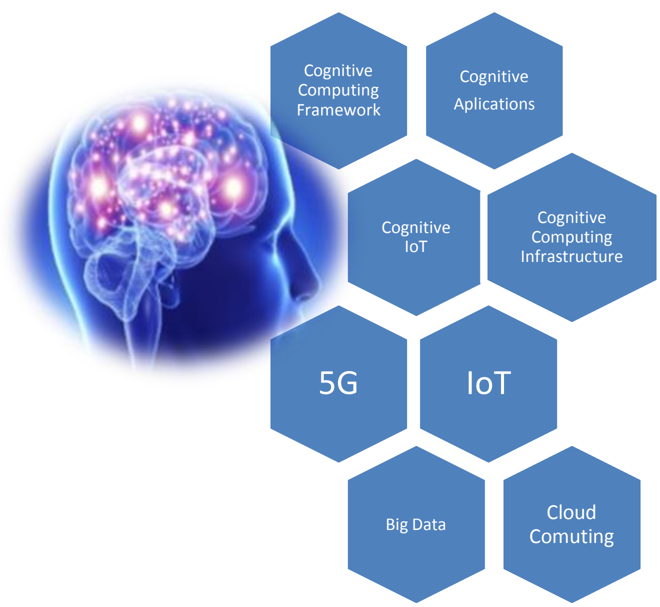

Fig. 1: The system architecture of Cognitive IoT.

Example Cognitive IoT

Project Intu. IBM launched the experimental release of its Project Intu, a new system-agnostic platform designed to enable embodied cognition. Embodied cognition is the application of artificial intelligence to form factors, such as robots, devices or other objects. Project Intu enables developers to embed Watson functions into various end-user devices form factors to create new cognitive-enabled experiences. IBM is taking cognitive technology beyond a physical technology interface like a smartphone or a robot toward an even more natural form of human and machine interaction. Project Intu allows users to build embodied systems that reason, learn and interact with humans to create a presence with the people that use them–these cognitive-enabled avatars and devices could transform industries like retail, elder care, as well as industrial and social robotics. The new IBM project is available on the Watson Developer Cloud, Intu Gateway and GitHub. With roots in IBM Research, Project Intu is an effort to extend cognitive technology into the physical world in form factors like robots, avatars, spaces and internet of things (IoT) devices. Developers can tap into Watson services like the Conversation, Language and Visual Recognition APIs to apply different cognitive behaviors to devices [31].

Echelon InSight. The Internet of Things pioneer, Echelon Corporation, unveiled cognitive vision-based technology that can enable a wide range of smart city and smart campus applications. Echelon InSigh utilizes artificial intelligence in vision-enabled edge devices, optimized for Industrial Internet of Things (IIoT) applications. With InSight, traffic data is collected and processed at the edge of the network instead of on a central server and uses the Lumewave by Echelon lighting platform to transmit traffic information, reduceresponse time and improve reliability. This architecture enables faster action in response to changing conditions and minimizes network bandwidth requirements [31].

ABB and IBM. The new suite of breakthrough solutions developed by ABB and IBM will help companies address in a completely new way some of their biggest industrial challenges, such as improving quality control, reducing downtime and increasing speed and yield of industrial processes. These solutions will move beyond current connected systems that simply gather data, to cognitive industrial machines that use data to understand, sense, reason and take actions which support industrial workers and help eliminate inefficient processes and redundant tasks. ABB and IBM will leverage Watson's artificial intelligence to help find defects via real-time production images that are captured through an ABB system and then analyzed using IBM Watson IoT for Manufacturing. Previously these inspections were done manually, which was often a slow and error-prone process. By bringing the power of Watson's real time cognitive insights directly to the shop floor in combination with ABB's industrial automation technology, companies will be better equipped to increase the volume flowing through their production lines while improving accuracy and consistency [31].

Conclusion

The combination of the Internet, brain science and artificial intelligence is related to a number of fields and has some influence on them. This research has inspired us to explore if it is possible to build an artificial intelligence system model simulating the Internet brain.

In this article, firstly (section 2) the background and definition of Internet of Things, Cloud Computing, Big Data, Industrial Internet, Virtual and Augmented reality are given. By integrating intelligent thought into IoT, we presented a new concept of Cognitive Internet of Things (CIoT) in this paper. CIoT can apperceive current network conditions, analyze the perceived knowledge, make intelligent decisions, and perform adaptive actions, which aim to maximize network performance in section Finally in section 4 we presented application examples which were based on the concept of CIoT. The new achievements in these fields will be introduced in our papers in the future. We will model the CIoT network topology and design cognition-process-related technologies, which illustrate how those novel designs can endow CIoT with intelligence and fully improve a system's performance.

Different from other CIoT survey papers, the main contribution of this paper is that it focus on area specific architectures of CIoT applications and highlights the challenges and possible research opportunities for future CIoT researchers who could work in architecture as well as in CIoT as a whole.

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