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Discussion on the Definition and Construction Principles of City Brain

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***Abstract*—This paper makes a preliminary discussion on the generation, composition, and construction principles of city brains, proposing that the Internet has changed significantly in the structure through 50 years' development, and it is evolving from a net-like structure to the brain model. The combination of the Internet brain model and the construction of smart cities is the root cause for the generation of city brains. By analyzing the features of the Internet brain model, three principles for the construction of city brains are presented. The first principle is to establish a unified technology framework for city neurons across the world; the second is to achieve the human-computer dual intelligent control over city neurons, and ensure the human has the priority of control; and the third is to set the information routing meeting the city's needs, realizing the cloud reflex arc of the city brain.**

Keywords-City Brain; Smart Cit; City Neuron; City Cloud Reflex Arcs

I. INTRODUCTION

Since the beginning of the 21st century, a number of "brain" concepts have appeared in the fields of cutting-edge technologies, such as Google Brain, Baidu Brain, Alibaba Brain, 360 Security Brain, Tencent Super Brain in the business community; as well as City Brain, Industrial Brain, and Aviation Brain in the industrial community, of which, the emergence of City Brain has attracted great attention from the government, academia and industry. In China, the cities like Hangzhou, Shanghai, Beijing, and Guangzhou have proposed and implemented different construction programs of city brains [1].

It is put forward in our study that "the Internet is evolving from a net-like structure to a brain model through decades of development. This significant change will also greatly affect many fields such as technology, economy, industry, and city construction. City Brain is the product from the combination of the Internet brain model and the construction of smart cities. [2]"

When City Brain has become a new hot spot in advanced technologies and industries, there is not a unified definition for this concept in the academia and the industrial community. Regarding how to construct the city brain, there are different viewpoints and design plans. For example, the city brain on the basis of the Internet brain model is one of such viewpoints, while some companies and researchers believe that the city brain is a technical complex combining the Internet of Things, big data, cloud computing, and artificial intelligence [3], or that it is an information system that manages and controls various parts of a city through an artificial intelligence system [4].

In this case, a big question is which viewpoint and theory should be followed to carry out the top-level design of city brains. In-depth research can avoid problems like the generation of information islands, repetitive construction, and errors in strategic planning. All these problems will be deeply explored and discussed in this paper.

II. PROPOSAL OF THE INTERNET BRAIN MODEL

Since 1969 when the Internet was born, the net-like structure has always been its most prominent feature. It is defined as "an international Internet that connects all the computer networks across the world" [5]. As indicated by various phenomena, the Internet has been gradually evolving from a net-like structure to a brain-like model since the beginning of the 21st century, after the TCP / IP protocol in 1974, the World Wide Web in 1989, and other technologies laid a solid foundation.

Following the brain-like neuron network represented by the social network in 2004, the central nervous system by the cloud computing in 2005, the sensory nervous system by the Internet of Things in 2009, the motor-like nervous system by the cloud robot and unmanned technology in 2012 [6].

Google Brain, Baidu Brain, Alibaba Brain, Tencent Brain, 360 Security Brain, City Brain, Industrial Brain and other Internet industry-level brain systems have continuously appeared since 2013, and the prototype of the Internet brain is becoming more and more clear (as shown in Fig. 1). On this basis, the authors put forward the definition of the Internet Brain as below [7]:

Internet Brain is a brain-like giant system architecture forming in the evolution of the Internet towards a structure that is highly similar to the human brain, and it has an increasingly-mature brain-like visual system, an auditory system, a somatosensory system, a motor nervous system, a memory nervous system, a central nervous system and an autonomic nervous system. Various elements of the society (including but not limited to human, AI system, production materials and production tools) and various elements of the nature (including but not limited to rivers, mountains, animals, plants, and the space) are connected by the Internet brain through brain-like neuron network (Big SNS), thereby the

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interaction between people and people, people and things, as well as things and things are achieved. The Internet Brain can also realize recognition, judgment, decision, feedback and transformation of the world through the cloud reflex arc, driven by the cloud swarm intelligence and the cloud machine intelligence.

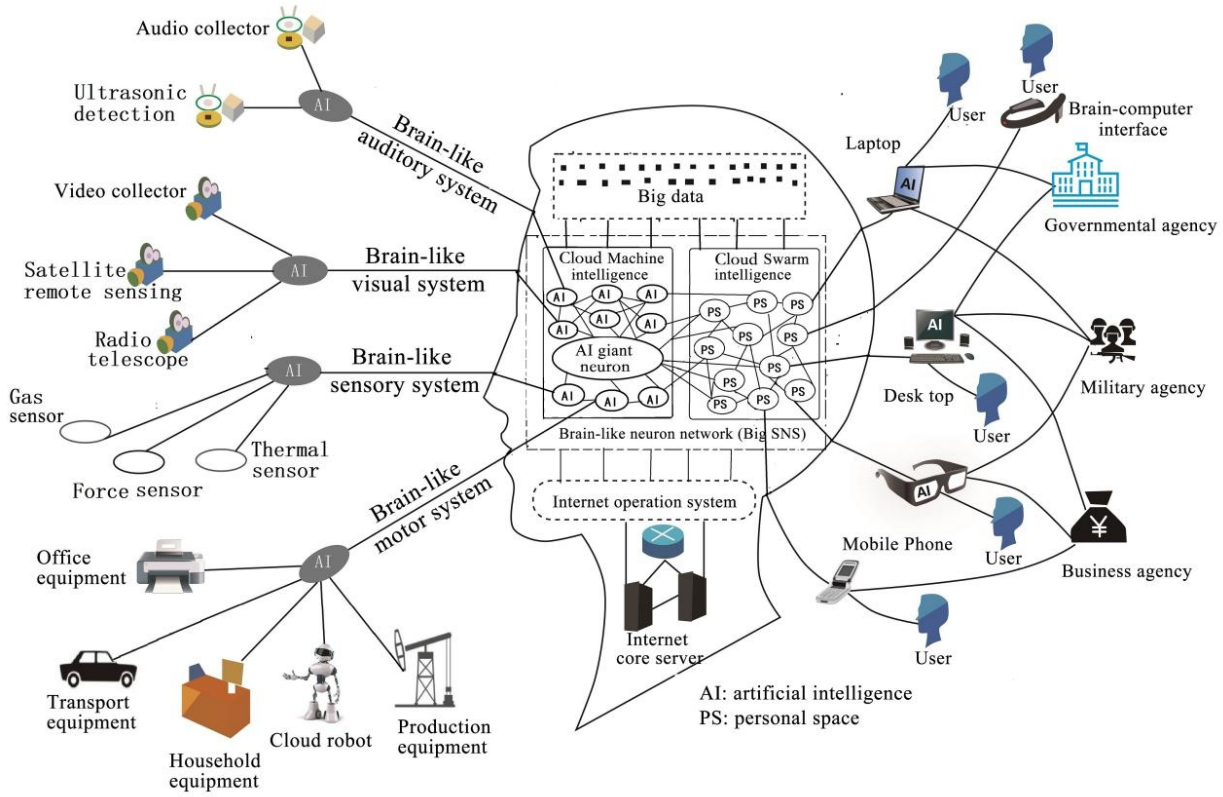

Figure 1. Internet brain model.

In the Internet brain model, we can see three major features. Through the analysis of these three features, a theoretical basis can be provided to determine the principles for the construction of city brains.

The first major feature of the Internet brain model is that the brain-like neuron network is interconnected with all things. Like the neuron network being as the most important structure of the biological brain [8], the brain-like neuron network is also one of the most important structures of the Internet brain, as shown in Part 1 of Fig. 1, everything in the world, including people, smart devices, natural elements, applications, control systems, virtual artificial intelligence characters, etc. in the real world, should be mapped to be a neuron node in the brain-like neuron network of the Internet brain. In such a neuron node, all things in the world can synchronize and upload their own information and knowledge, and run their own functional programs. More importantly, all things in the world can achieve mutual following, communication, information sharing and group decision-making through their own neuron nodes.

The second major feature is dual intelligent center control of the cloud swarm intelligence and the cloud machine intelligence. As shown in Part 2 of Fig. 1, billions of people form the cloud swarm intelligence [9] and tens of billions of devices form the cloud machine intelligence through the Internet brain neuron network. The power to drive the Internet brain model in this way comes from human intelligence and machine intelligence. Since the Internet brain has formed and developed essentially providing the human services, it is required to ensure that the human intelligence has the top priority of control when the Internet brain architecture is running.

The third major feature is the formation of cloud reflex arc, as shown in Part 3 of Fig. 1. With the inclusion of human users, various sensors, cloud robots, smart devices, optical fibers, and mobile communication lines [10], the nervous systems of the Internet brain model have been gradually improved. Similarly, the neural reflex function in the biological brain has also begun to form in the Internet brain model. We call this nerve-like reflex phenomenon in the Internet brain model a cloud reflex arc. It is the key for the Internet brain model to react to various problems both in the real world and in the virtual world, make decisions, and take actions, thereby generating superintelligence. Similar to the biological neural reflex arc mechanism, the cloud reflex arc in the Internet brain model also needs the participation of different types of neurons. For example, information is transmitted from one neuron node to another, and is continuously transmitted to other neurons as needed, thus realizing the cloud reflex arc process of the Internet brain model, i.e. receptor ---> afferent nerve ---> central nervous system ---> efferent nerve ---> effector [11].

III. GENERATION AND DEFINITION OF CITY BRAIN

In January 2009, Peng Mingsheng, the CEO of IBM first proposed "Smart Planet" [12], and the concept of Smart City extended from this has greatly promoted the process of city modernization in various countries around the world. With the acceleration of the brain-like process of the Internet, and the continuous deep exploration to the structure of the human society, the construction of smart cities will inevitably be affected by the Internet brain model.

We should say that the smart city is the result when the Internet has developed to a certain extent, and naturally spread and deepened to the construction of cities. Therefore, the Internet's development trends and evolutionary laws must be considered in the construction of smart cities. As a product from the combination of the Internet brain and the construction of smart cities, the city brain will inherit basic features of the Internet brain. Therefore, the smart city system realized on the basis of the Internet brain architecture can also be called City Brain, which is defined in detail as follows [13]:

City brain is the product of the combination of the Internet Brain architecture and the construction of smart city, and is a city-level brain-like complex intelligent system. With the joint participation of human intelligence and machine intelligence, and the support of cutting-edge technologies such as the Internet of Things, Big data, Artificial intelligence, Edge computing, 5G, Cloud robots, Digital twins, etc., City neuron network and the reflection arc of City cloud are the focus of City brain construction. The role of City brain is to improve the operation efficiency of the city, solve the complex problems faced in the operation of the city, and better meet the different needs of the city members. City brain is not only limited to a city or a region. When the world-wide city brains are connected together, City brain will eventually form the World Wide Nervous System (World Brain), helping human beings develop together as a whole.

IV. PRINCIPLES FOR THE CONSTRUCTION OF CITY BRAINS

In the discussion of the first section, three major features of the Internet brain model were proposed. As a subset of the Internet brain model, the city brain is essentially a complex brain-like giant system that links the wisdom of city residents and the intelligence of city devices. Therefore, three principles can be determined for the construction of the city brains according to the key features of the Internet brain model.

The first principle is to build a unified neuron node construction framework in the city. The construction of the city brain-like neuron network based on the Internet brain model can, on the one hand, organically link every resident, device and software system within the city together, including buildings, street lights, cars, gas pipelines, city residents, doctors, commercial institutions, municipal managers (mayor), intelligent systems that monitor urban traffic, medical treatment, and security [14], etc., providing unified neuron node services (as shown in Fig. 2).

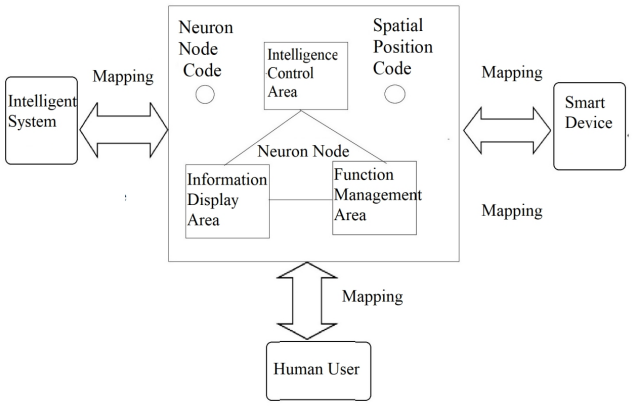

Figure 2. Brain-like neuron network of the city brain.

In this node space, people, things, and systems can map and synchronize their own information, and run corresponding management and control programs, realizing mutual following and information exchange between people and people, people and things, things and things, people and systems, things and systems, and systems and systems [15] through the node space. We make a point that there should be five main components in a city neuron node, namely:

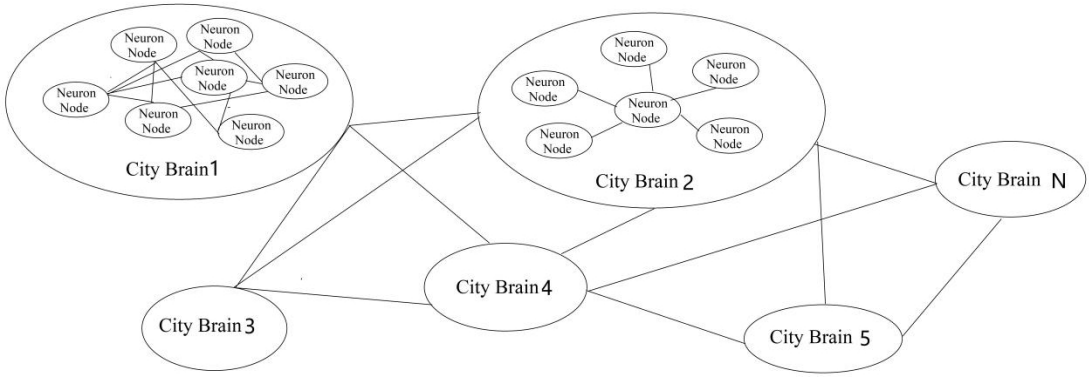

Figure 3. Five major components of the city neuron node.

1) Information display area: to control the display authority of the information issued by the mapping object.

2) Function module area: to provide different function modules according to the requirements of different mapping objects.

3) Intelligent control area: an area to manage information display and functional modules, requiring that both the human control and the AI control are enabled at the same time.

4) Neuron node coding: to uniformly code the neuron nodes of all city brains.

5) Spatial position coding: to uniformly code the geographic location and altitude of the neuron nodes of all city brains, identifying their positions (if it is a network intelligent system, the spatial position will be 0) [16].

On the other hand, it is also more important that each neuron node should have a unified technical structure, node coding, and URL coding, which should be unified not only within a city, but also in terms of the specifications for the neurons of different cities; not only in the city brain, but also in special brains such as agricultural brain, industrial brain, architectural brain, etc., in order to ensure that both the city brain and the industry brain are subsets of the Internet brain. The city brains and industry brains can achieve cooperation through the Internet brain architecture (as shown in Fig. 3).

The second principle is that each city neuron node realizes human-computer dual intelligent control, with the human having the top priority of control. That means human users can log into the city neuron node to control the city neurons and realize the desired functions. In the case of human users, the AI program controls this neuron node with the authorization of the human.

For example, the mayor of a city can log into his neuron node space to synchronize his information and data, handle certain city matters, and observe the situation on any emergency site in the city through the site camera linked; when the mayor temporarily log out of the node, the AI program will handle documents and requests according to the authorization of the mayor.

Similarly, for an automatic car running in the city, under normal circumstances, the AI program controls the car and synchronizes the information to the car's city neuron node at any time to interact with other city neuron nodes, but when the car has any fault, the human administrator will be able to log into the car neuron node to control the automatic car.

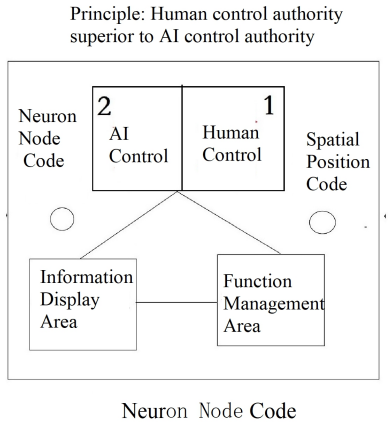

Figure 4. Human's top priority of control over remote neuron nodes.

In order to ensure that the human has the absolute authority of control, it must be ensured that each neuron node, whether it is a person, a thing or a system, has at least one human user with the top priority of control over the node. This is to avoid the human loses the control authority once all the control authority is completely given to the computer and the AI system and then they will solely perform decision-making [17] (as shown in Fig. 4).

The third principle is to establish the information routing between city neuron nodes according to different needs of cities, realizing the cloud reflex arc of city brains. When people, devices, things, and systems in a city are all linked to the brain-like neuron network, a large number of the city's needs, problems, and services can be met, solved and provided through the collaboration of various neuron nodes in the city. From sensing the needs of a city upon an incident to the handling by the central nerve, and finally to giving feedback to the site for execution, series of urban cloud reflex arcs are formed to drive the operation and development of communities, institutions and enterprises within the city.

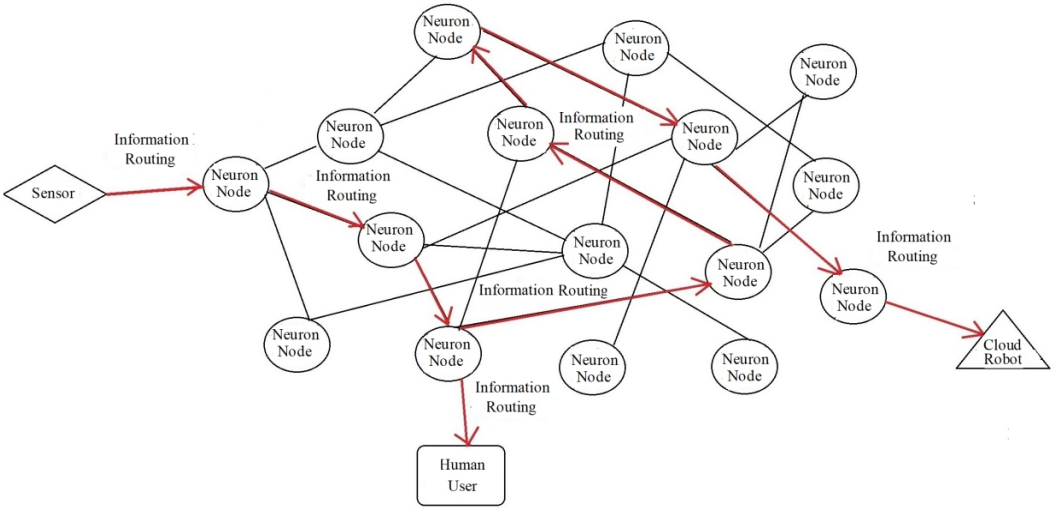

Figure 5. City cloud reflex arc mechanism.

In this case, the information should not only be transmitted between one neuron node and another, but also be transmitted from one neuron to another based on the needs, and further transmitted to the next the neuron node according to the path

planning, until all the needs are met completely (as shown in Fig. 5).

For example, in a building, when a sensor detects fire information, it will dispatch the incident to the disaster management node through its own city neuron node. The AI control program in the disaster management node will make a judgment according to the fire information, and continuously transfer the judgment result and fire information to the human manager [18], and then wait for the feedback from the human manager.

If failing to receive the feedback from the human manager within the specified time, and having been authorized from the human manager before, the AI control program will generate a new command after confirming the location and the severity of the fire according to the information of the incident, and send it to the mobile fire-fighting robot. After receiving the command, the mobile fire-fighting robot will move to the place where the fire occurs, and perform fire-fighting task. The mobile robot also has the AI control program and the human control program. If the human command appears when the mobile robot is executing an AI control command, then, the priority of control will be given to the human command.

V. SUMMARY

Considering from the origin of City Brain, it is not a system existing independently, but the product when the Internet combines the construction of cities while evolving into the brain-like model. The neuron network of a city brain is not limited to the geographical boundary of the city, it will often expand to other cities or even continents. Besides, the cloud reflex arc of a city brain can also occur in other cities. Therefore, determining unified principles for the city brains of different cities will be a key topic to be further studied in the future.

In this paper, three principles are proposed for the construction of city brains. However, they still belong to the top-level design of city brains. In the future, it is necessary to further study how the cutting-edge technologies such as sensors, cloud computing, cloud robot, artificial intelligence, spatial coding, and unmanned vehicles support the implementation of these principles.

In addition, low-level principles and standards need to be developed for the construction of city brains, for example, what URL coding standards should be selected, what control programs should be included in a neuron node, and how to comb the paths of city cloud reflex arcs through experts' wisdom in order to meet various needs of cities? All these are the topics to be further studied in the future.

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