Connotation and Application of Human-like Smart City

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Abstract. At present, smart city construction has become a global hotspot, so how to build smart city efficiently and accurately has become a problem that needs to be explored and solved. Based on the theory of human-like life, the mapping relationship between basal model and city skeleton, building information modeling (BIM) and city flesh, Internet of Things (IoT) sensing and city nerve, spatiotemporal data with cloud computing and city brain, smart application and city behavior, standard system and city gene were analyzed respectively. The technology architecture of integrating geographic information system (GIS), BIM and IoT was proposed. The framework of a human-like smart city platform was given. Based on the technology architecture and framework, the application of smart fire protection was studied, realizing integration of three technologies, which provided an effective reference for the future research and practice of smart city.

Keywords: Human-like life, Smart City, GIS, BIM, IoT, Smart fire protection.

1. Introduction

Over the past few decades, cities in China have expanded rapidly along with the economic construction and social advancement. However, the imbalance between city development speed and planning often leads to problems such as resource shortage, traffic congestion and environmental pollution, etc. In recent years, the concept of smart city is carried out and has attracted favorable attention with the ever-growing need for solving these city problems. The basic idea of the smart city is integrating the digital twin cities deeply with the Internet of Things (IoT) technology. Moreover, it emphasizes the deep mining and real-time utilization of city data. Therefore, the city management abilities can be significantly enhanced, to meet exquisite, dynamic and intelligent requirements of modern city development.

Since the concept of smart city was firstly proposed by IBM in 2009 [1], plenty of studies on Chinese smart city development have been carried out. For example, Li et al. [2] discussed the basic theories and inevitable trends about the evolution from digital city to smart city. Xu et al. [3] proposed the vision and strategic goals of smart city with Chinese characteristics. In addition, the application of city-level functions under the concept of smart city has also received wide attention. The research results cover many aspects such as transportation, residential service platform, operation and maintenance and safety management [4-8]. However, smart city is a huge project with complex functional systems, how to realize real-time information fusion under different functional systems and promote coordination between various city functions is still a key issue in the current smart city construction.

In recent years, the concept of human-like life has attracted attention increasingly. It establishes a mapping relationship between complex engineering systems and human body, and uses human body concepts to analyze and promote the coordination between various functional systems in engineering systems. At present, it has been applied in the smart ocean development [9]. In consideration that city and human systems are highly similar in many aspects, it is feasible to introduce the concept of human-like life into smart city systems, where preliminary researches have been carried out. For example, Jiang et al. [10] investigated the theoretical systems of constructing human-like city with the experience of city life forms, city metabolism, city ecology and other related fields. Liu [11] analyzed the causes of city problems from the perspective of human-like city. Gao et al. [12] combined the smart city and ecological city theory together and proposed a new representation of city ecological wisdom from the perspective of bionics.

This paper analyzes the mapping relationship between the human-like life and smart city construction, and proposes the smart city management system by integrating geographic information system (GIS), building information modeling (BIM) and IoT. Additionally, we realize one city-level application of smart fire protection in the construction of smart city. The results of the present paper can provide reference for further research and practice about smart city.

2. Connotation of Human-Like Smart City

The life characteristics of smart city have been put forward by researchers by introducing the classical theories of biology and life science into the construction of smart city. But it has not yet been combined with human behavioral trait. Researching smart city in view of human-like life, its connotation is specific and vivid. Referring to the both macroscopic and microscopic structural and behavioral characteristics of human body, it can be used for analogy to guide the construction of digital twin cities in planning, construction and operation of city. Smart city is like a human being, whose skeleton, flesh, nerves and brain depend on each other. They are all important parts of the living body, and carriers of the behavior.

2.1 Basal Model: City Skeleton

In the construction process of smart city, city skeleton is composed of geological information, geographic information and city planning information. Among them, veracious geological information provides a strong guarantee for the rational development and utilization of underground space, and plays a basic bearing role in the process of city planning and construction, which mainly involving engineering geology, hydrogeology, groundwater resources, etc. Geographic information runs through the whole process of city planning and construction. It reflects the city outlook and restricts the formulation of city planning and implementation of city construction. City planning is the basis of city construction and guides the direction of city development. Smart city construction and operation management need to be carried out based on these types of information. Therefore, it should be regarded as the basal model of smart city.

2.2 BIM: City Flesh

BIM is a digital information platform based on 3D technology to realize information management in the whole life cycle of engineering. On the one hand, BIM can aggregate, analyze and process city sensing data as the basic data platform for various applications in smart city. On the other hand, BIM can provide support for smart city decision-making and visualization based on massive data, with security, reliability, open sharing, and better connection with cloud computing [13]. The various engineering models included in BIM are an important part of smart city construction. Therefore, using BIM as the flesh of digital cities has brought new vitality to the development of digital cities.

2.3 IoT Sensing: City Nerves

The IoT is a kind of network that associates items with the Internet through information sensing devices to realize the positioning, tracking, identifying, monitoring and management of items. The IoT is usually divided into the sensing layer, the network layer and the application layer. Among them, the sensing layer is the source of IoT data, which dynamically monitoring and timely feedback sensing data through the IOT sensing device. Therefore, the sensing layer can be regarded as city nerve. Commonly used sensing devices include: radio frequency identification devices (RFID), infrared sensors, global positioning system, laser scanners, etc. Common monitoring data consists of the following three categories:

1. Visible flow: traffic flow, people flow;
2. Invisible flow: energy flow, fund flow, information flow;
3. Ecological environment data: meteorology, air quality, water quality, soil quality, energy consumption, noise.

2.4 Spatiotemporal Data with Cloud Computing: City Brain

The construction of smart city requires the city brain. The data aggregation process of the smart city top-level platform is analogous to the diet process, that is, the evolving of city life is ensured by the continuous import of different types of data, including GIS data, BIM data, and IoT data. Then, the accumulation and application of data needs to use the brain to help the city complete the thinking and decision-making functions, so that the city has good self-regulation ability and can interact with human beings. With the advent of the big data era, the traditional way of city planning, construction and operation management can no longer meet the actual needs. It is urgent to rely on big data processing and deep mining technology to help the construction of smart city.

With the development of smart cities everywhere, developing cloud computing is the core foundation for building the city's smart brain. Cloud computing is a new type of information resource management and computing service model. Because of its large scale and good scalability, it has super computing power. Providing service reliability through safeguards makes cloud computing more reliable than local computers. The cost of massive data management is greatly reduced by special fault tolerance measures.

The construction of "city brain" focuses on the research and application of spatiotemporal data and reshapes the city management mode with data paradigm. At the same time, in order to ensure the validity of the imported data, it is necessary to analyze and process the collected data for city management. The use of massive spatiotemporal data to solve various problems in city planning, construction, and operation management is a new mode of city governance. As the brain of the smart city system, spatiotemporal big data is the basis for making the right decision.

2.5 Smart Application: City Behavior

The goal of smart city research and practical exploration is to achieve the goal of smart city application. Recently, smart city has made progress in different fields, such as smart park, smart transportation, smart water, smart law enforcement, smart emergency, smart energy, smart medical treatment, smart government affairs, smart education, smart finance, etc. City behaviors can be guided by different smart applications. For example, through the smart transportation system, vehicles can be guided to avoid traffic congestion, and road traffic information can also be obtained through statistics to plan the opening and closing of different road sections for road maintenance.

2.6 Standard System: City Gene

The precise inheritance, metabolism, and function of human are all regulated by DNA, which has a large and regular grammatical system. It can also be considered as the human body's standard system. Similarly, certain rules of conduct must be followed in the construction of smart city, whether the format and precision of data storage and exchange, or the process of data processing and analysis. Laws, regulations, industry standards and other requirements must be met. The BIM data format has not yet formed a unified standard. Some data standards are also incomplete in smart city application. For example, the unmanned vehicle needs to adopt a precise base map, while the precision and format of base map has not been unified, which brings great difficulties to practical application. Therefore, in the construction of smart city, it is necessary to establish various standard systems, and formulate a genetic system for city development, to help smart city develops along the right track.

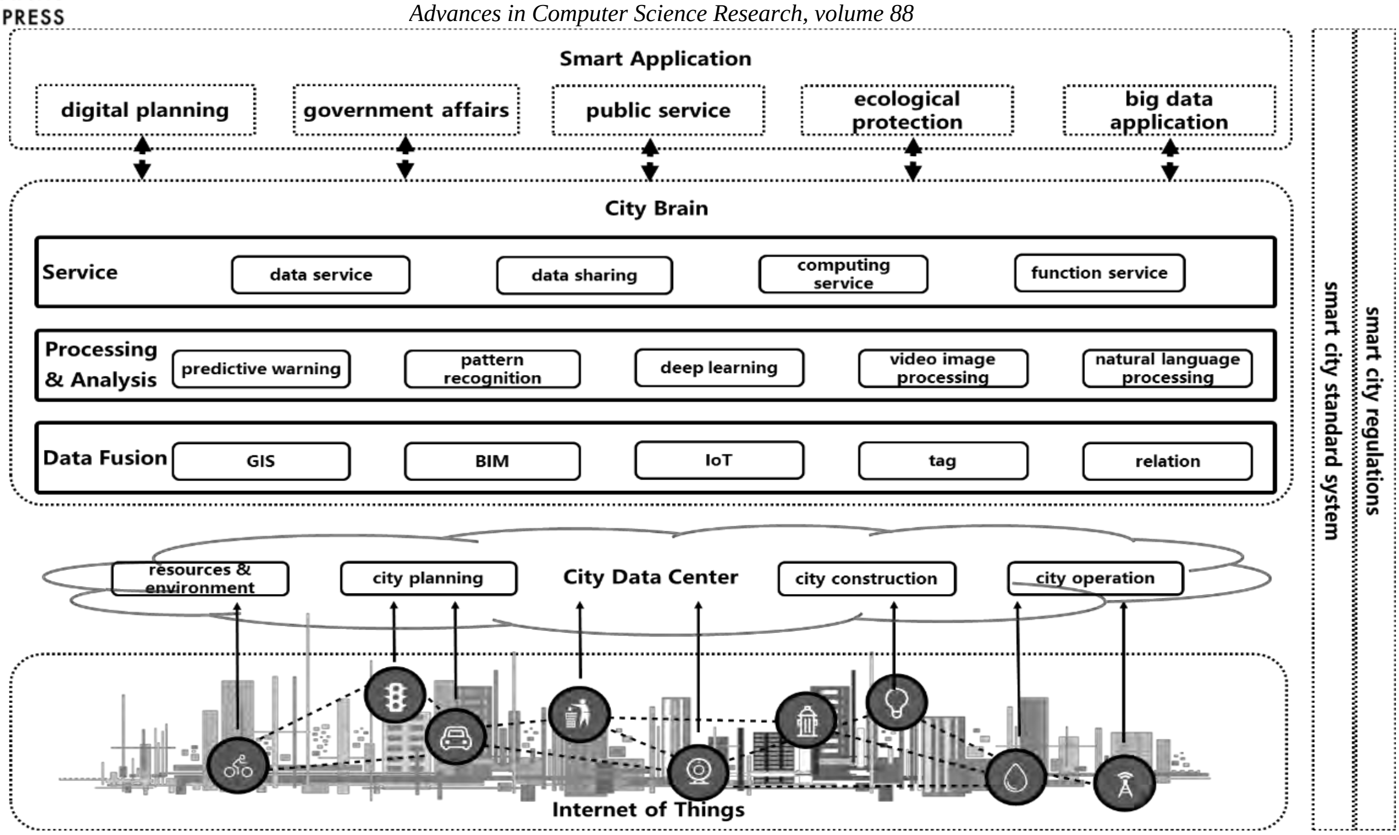

Fig. 1 Framework of human-like smart City Platform

3. Technology Architecture and Framework

3.1 Technology Architecture of Integrating of GIS, BIM and IoT

GIS focuses on the storage, analysis and display of spatial geographic information, while BIM is the digital form of manmade buildings and structures, including shape and information. The two are not opposites, but describe the space and components of the city in slightly different ways at different scales. The scope of GIS is broader, including various elements such as the natural environment outside the building and the human economy. BIM is more concentrated on the building and its internal components and space. Both are represented as spatial entities and their corresponding attribute information.

With the development of technology and applications, GIS is no longer limited to land management, resource allocation analysis, planning, etc., but evolved into science of where. The boundaries between BIM and GIS will become blurred and integrated. BIM can be seen as extension of the GIS at the building part, managing building components and their information spatially. It can be said that the combination of GIS and BIM completely reflects the static city in the digital space, that is, the skeleton and flesh of the city, including the complete three-dimensional model of both above-ground and underground, natural elements and artificial buildings. They are not only the basic data of the digital city, but also the spatial reference of smart city.

However, with only skeleton and flesh, the city is static and plant-like, lacking dynamic vitality. Not only does the natural environment continue to change, but people in the city are constantly interacting with other people and the environment. Dynamic city requires not only dynamic sensing, but also immediate feedback. IoT dynamically acquires kinds of status in the real city through sensors and networks, and feedbacks the reality through digital control devices. IoT builds a bridge between real world and digital world, reflecting dynamic information in the city into the digital space, while feeding back operations in the digital space to the control devices in real world. Feel on the one hand and feedback on the other hand, like the human nerves.

GIS and BIM provide accurate spatial positioning for IoT sensors and a spatial context for IoT's sensing data. The IoT data can then be spatially aggregated to completely reflect the status distribution of the real space. On the other hand, the digital control device has a corresponding embodiment in BIM, which can accurately know the effect of the feedback operation.

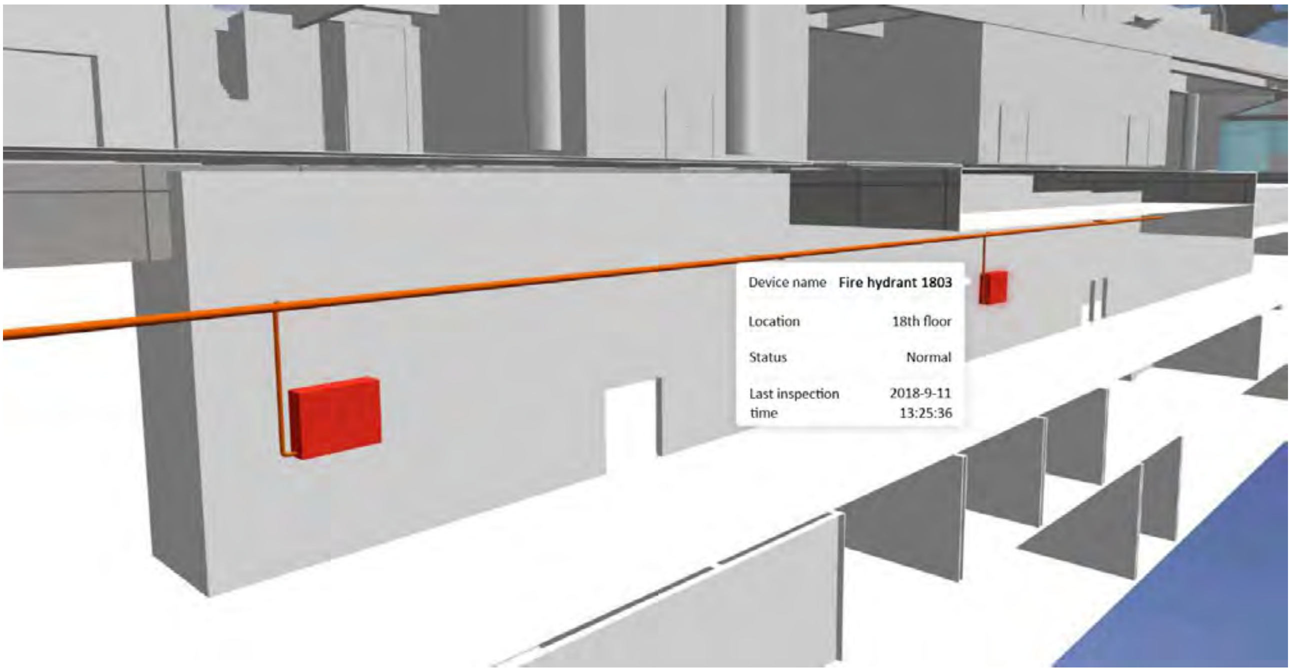

Fig. 2 IoT sensing data in BIM

3.2 Human-Iike Smart City Platform

According to the connotation of the human-like smart city, and the technical architecture of integrating GIS, BIM and IoT, the Human-like Smart City Platform (HSCP) is constructed, which is illustrated in Fig. 1.

The platform is based on the city data center, which includes resource and environment data, planning data, construction data, and operational data. Dynamic data generated by sensor networks distributed throughout the city is an important data source of city data centers.

The city brain is the central core of the human-like smart city. Its function is divided into three levels: the bottom level is the data fusion layer. For the various data in the city data center, the spatial attributes based on GIS+BIM are used to fuse the IoT data. At the same time, based on the data attribute tag and spatial location to establish the association between the data. The middle level is the processing and analysis layer, based on the fusion data, using deep learning, pattern recognition and other methods to deepen the data value, extract the real and effective data information. The top level is the service layer, which provides data services, sharing services, computing services, and function services for various smart applications.

Smart city applications are the embodiment of city data and city brain that function and feedback. Centralized city data and shared city brain are combined into different city applications to play a smart role in all aspects of city construction and operation.

In addition, the standard system and regulations of smart city are through the entire platform, including not only hardware standards of the IoT, data standards, and service standards, but also regulations on information security, government affairs, environmental protection, etc.

4. Application

The smart city covers many aspects. In this section, a smart fire protection system based on the integrating of GIS, BIM and IoT is carried out to demonstrate the advantages of the human-like smart city platform.

As an important part of smart city, smart fire protection system is supported by intelligent identification and intelligent processing. Based on digital geographic information, along with mobile positioning system, and IoT alarm technology, a series of fire protection processes can be realized, such as the fire point automatic identification, automatic alarm transmission, fire-fighting vehicle scheduling and route optimization, optimal fire-fighting location selection, etc. The advantages of the smart fire protection system can be concluded as follows:

1. Aggregating real time sensing and monitoring data. The basic smart fire protection IoT unit consist of sensors like smoke detectors, temperature detectors, flammable gas detectors, manual alarm buttons, etc. and monitoring devices on fire hose water consumption, water pressure, fire pool level, etc. For example, the location information, status information and maintenance information of monitoring device are shown in Fig. 2. These include the operating status of fire alarm equipment and fire water system, as well as the information of the fire point. By collecting and analyzing this kind of information, not only can the fire alarm equipment and fire water system with abnormal operation be replaced in time, but also the location of the fire station site and the reserve of fire equipment can be optimized.

Fig. 3 Fire-fighting scheduling using GIS

2. Improving the fire-fighting scheduling efficiency by GIS. Geographic information data including roads, buildings, underground parking lots, chemical zones, fire stations, forests, electrical plants, transformer stations, etc., constitute the basic skeleton of smart fire protection. By receiving the fire alarm information, the fire intensity and fire-fighting demand of the fire point are analyzed to automatically match the best fire station; by analyzing the road mileage information and vehicle congestion information, the driving route of the fire vehicle is optimized, so that fire-fighting vehicle can be placed in the scene in the shortest time with enough capability, as shown in Fig. 3.

3. Improving the fire-fighting disposal efficiency by BIM. With adequate BIM models, information of building and fire-fighting equipment can be better utilized by firefighters. For example, information such as building materials, fire exits, and fire equipment placement points on the burning floor can be better queried through the BIM model in the smart fire protection system, as shown in Figure 4. Furthermore, the IoT sensing data and the video data obtained by the monitors on site can provide a good reference for firefighters to choose the best strategy.

Traditionally, the fire-fighting alarm system, on-site command system and dispatch system are divided separately. They cannot play the joint action and serve the whole process of fire protection through real-time data aggregation and analysis. By integrating GIS, BIM and IoT, the smart fire protection system can provide better service.

5. Conclusion and Prospects

This paper proposed the connotation of human-like smart city, and provided the technical architecture integrating GIS, BIM and IoT for the planning, construction and operation management of smart city. With application on smart fire protection, we showed the ability of this technical architecture. GIS can optimize the driving route for fire-fighting vehicles, BIM can display fire equipment layout and detailed information clearly, and IoT data can provide real time information for firefighters effectively. These three technologies will be integrated in different modes to different smart city applications. In the process of building smart city, GIS, BIM, and IoT have their own advantages and are indispensable. However, in the huge system of smart city, how to effectively integrate these three technologies in different fields still needs to be explored continuously.

The reason why people are different from other creatures lies in the highly developed brain,that is the wisdom. For smart city, integrating GIS, BIM, and IoT enables the mapping from real city to digital city, providing solutions for smart applications in one certain type of city behavior. Further, it is necessary to aggregate the massive spatiotemporal data of various smart applications, and use cloud computing to establish the relationship between data from a global perspective, to understand the nature of city phenomena and feedback the behavior of smart city. In addition, as city genes, research and formulation of the standard system should also be taken seriously, to regulate the construction and application of all formulation of the standard system should also be taken seriously, to regulate the construction and application of all aspects of smart city.

Fig. 4 Fire-fighting disposal using BIM

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