Study on the Comprehensive Computational Thinking Transformation of Urban Planning Discipline in the Era of Big Data

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Abstract

In the era of big data, with the development of computer technology, especially the comprehensive popularization of mobile terminal device and the gradual construction of the Internet of Things, the urban physical environment and social environment have been comprehensively digitized and quantified. Computational thinking mode has gradually become a new thinking mode for human beings to recognize and govern urban complex system. Meanwhile computational urban science has become the main discipline development aspect of modern urban planning. Computational thinking is the thinking of computer science using algorithms based on time complexity and space complexity, which provides a new paradigm for the construction of index system, data collection, data storage, data analysis, pattern recognition, dynamic governance in the process of scientific planning and urban management. Based on this, this paper takes the computational thinking mode of urban planning discipline in big data era as the research object, takes the scientific construction of computational urban planning as the research purpose, and adopts literature research methods and interdisciplinary research methods, comprehensively studies the connotation of the computing thinking mode of computer science. Meanwhile, this paper systematically discusses the system construction of urban computing, model generation, the theory and method of digital twinning, as well as the popularization of the computational thinking mode of urban and rural planning discipline and the scientific research of computational urban planning, which responds to the needs of the era of the development of urban and rural planning disciplines in the era of big data.

Keywords

Big Data Era, Computational Thinking, Computational City, Digital Twin City

Introduction

In the era of big data, hundreds of millions of computers and mobile devices are constantly creating an astonishing amount of information, and more and more problems need to be solved by computing. Computational thinking characterized by formalization, programming and mechanization provides new important means and theoretical basis for scientific research and technological innovation, which is continuing and will continue to promote the development of contemporary science and high and new technology¹. The computational thinking of using the ideas and methods of computer science for problem solving, system design, and human behavior understanding enriches the way for human beings to transform the world².

In view of the historical opportunity provided by computing science for urban and rural planning, research institutions around the world have coincidentally carried out research on big data and urban planning, smart city and digital twin city. At the same time, famous colleges and universities have carried out relevant undergraduate and postgraduate degree training, such as in June 5, 2018, MIT School of Architecture and Planning and School of Engineering jointly formed Interdisciplinary undergraduate program combining urban planning and computer science. In September 2020, British UCL, the Bartlett Center for Advanced Spatial Analysis, began to recruit MSc Connected Environments. Thus it can be seen that the combination of computer science and urban planning has become the demand of The Times and the trend of historical development in the field of urban planning, whether in the field of urban planning research or urban planning education.

1. The background of Computational City

1.1. The emergence and development of Computer Science

1.1.1. The rapid development of computer technology based on Moore's Theorem

In the 1940s, due to the technological progress brought about by the Industrial Revolution and the practical need to solve complex mathematical problems, the first all-electronic computer ENIAC came out. From the initial 4-bit single-chip microcomputer to the current gigabit personal computer, its evolution speed has exceeded the Moore's Theorem proposed by Gordon Moore. In less than 100 years, the computer has changed from a theoretical Turing machine to a Turing machine with almost human hands³. The most popular machines are becoming more intelligent and miniaturized. At the same time, information technology has gradually entered millions of households from the laboratory. With the large-scale access to the Internet, data collection and entry have evolved from manual collection to automatic entry. Various types of sensors and sensor networks have broadened a wider range of relationships between people, people and things, and things. Information interaction has promoted the formation and development of computer technology.

With the gradual development of human civilization from a carbon-based civilization to a silicon-based civilization, social productivity has increased in an all-round way, humans' dependence on computers and virtual computing has continued to increase, and the application of Computer Science has become more extensive. In order to pursue higher-speed computing, various countries have provided all-

¹ Tang, P.H. (2003) *Introduction to Computing Subject*. 1st edn. Chongqing: Chongqing University Press.

² Dong, R.S. and Gu T.L. (2009) 'Computational Thinking and Computer Methodology', *Computer Science*, (01), p42.

³ Li, L. (2012) 'Computational Thinking——Concepts and Challenges', *China University Teaching*, (01): p9-14.

round support such as funds, technology, and talents for research in computing disciplines⁴, accelerating the process of transforming technology into productivity. At the same time technological progress and social development have enabled computer technology to be fully applied in all aspects of human society's production and life, putting forward new realistic requirements for computer information innovation and information sharing, and promoting the rapid development of computer technology.

1.1.2. The overall popularization of computer terminals and the formation of IoTs

With the development of computer technology, the functions and performance of computer terminals have been greatly improved, achieving intelligent development. At the same time, in order to meet people's actual needs, computer terminals present a variety of features with multiple functions. The emergence of digital communications has enabled the development of intelligent and globalized computer networks, as a result, computer terminals have been fully popularized worldwide, and it has been widely used in communications, commerce, education, data processing and other aspects, and it has also profoundly changed all aspects of human social life.

Due to the development of Internet technology and the comprehensive popularization of computer terminals, an Internet of Things system of "Everything is Internet" has been formed. It is a huge network formed by combining various information sensing equipment with the Internet, realizing the interconnection of people, machines and things at any time and any place⁵, further created the information exchange between the physical world, virtual world, digital world and society, and formed an Internet system of "things connected" in a general sense⁶. The Internet of Things is widely used in smart transportation, smart home, smart city, public safety, etc. In addition, under the current background of information development, the Internet has created a huge ocean of data. With the advent of Big Data Era, data attributes are accurately identified, and data resources are realized with the help of the Internet of Things. This will facilitate people's retrieval and analysis of all kinds of data they need, and dig deeper into the connections and internal laws between the things represented by the data, thereby greatly enhancing the human ability to recognize the world. The intelligent world of interconnection created by the Internet of Things has promoted profound changes in the production methods and lifestyles of human society.

1.2. The computational transformation of social life

1.2.1. Computing technology promotes the digitalization of social life

Modern society has entered the computer age, the popularity and application of computers in various fields has made it more and more closely related to people's daily lives. As the support of social life, computer technology is integrated into all aspects of our daily life through more diverse fragments, judging from the current performance, intelligence and networking will be the future development trend. At the same time, all kinds of computer equipment have also appeared one after another, people use computers more spontaneously to describe and process various social activities and solve various problems, people can use the Internet to carry out work, study, shopping, travel and other activities. At the same time, people can cross the barriers of time and space to quickly obtain a lot of information.

⁴ Zhao, Y.L. and Zhao, W.J. (2014) 'Analysis of the Current Situation and Future Trend of Computer Technology Development', *West Resources*, (05), p141-142.

⁵ Jia, Y.G. (2010) 'Research on the Application of Internet of Things Technology in Environmental Monitoring and Early Warning', *Shanghai Construction Technology*, (6), p65-67.

⁶ Zhou, Y.F. (2020) 'The application of Internet of Things technology in the construction of smart cities', *Jiangxi Building Materials*, (01), p8-9.

Information transmission becomes more convenient, promotes information sharing and communication, and makes daily life more convenient.

Computer technology has become an indispensable technical support for the development of modern society. With the continuous development of science and technology, computer technology has a wider range of applications and has become a necessary information infrastructure in the information age⁷. In the era of big data, people's daily life and work have become more networked, digitized and virtualized. The digitalization and virtualization of social life has gradually changed people's life patterns, greatly improved the efficiency and quality of people's production and life, and promoted the virtualization of social life.

1.2.2. Computer technology promotes the development of quantitative social management

The advancement of computer technology makes it play an increasingly important role in quantitative social management. Thanks to the computer's ability to store and analyze data, and various sensors connected to the Internet, the frequency of information exchange has increased, and the amount of various data has increased significantly. Various terminal devices and objects have built a smart management environment. The rapid development of various digital methods provides technical conditions for quantitative urban management⁸. Computer services not only optimize various social activities, but also promote the development of quantitative social management.

In the era of big data, with the development of computer technology and the popularization of the Internet, data resources must become an important resource and support for quantitative social management. After the management department has mastered all the data with management elements, it must conduct in-depth mining of all kinds of data and analyze the internal laws of social dynamic changes, in order to provide powerful decision-making support for each management department to achieve precise allocation of resources and improve management efficiency. On this basis, the seamless connection of the information systems of government management departments, realizing the interconnection, organic integration and sharing of data from multiple departments in the background, providing support for urban data analysis. At the same time, technological innovation in the application of social data, and practical and effective Internet + service management technology developed in multiple fields, and at multiple levels can comprehensively improve the intelligence and intelligence of quantitative social management, and provide guarantee for future urban development.

Figure 1. Motivation. Source: Painted by the author.

⁷ Bai, H.F.(2017)'On the application and development of computer communication technology in the new era', *Electronic World*,(12), p64.

⁸ Guo, L.Q., Lin, J.Y. and Wang, W.Y.(2012)'The application of refined urban management based on high-score remote sensing data', *Urban Development Research*,19(11), p57-63+69.

1.3. The Computational response of urban form

1.3.1. The City Form Mapping of Network Society

As a form of human settlements, cities can realize more efficient resource allocation. The city is the container of society, full of human culture, human social organization structure, social memory and people's life, etc., and it is also gradually developing and changing. With the popularization of the Internet, society is gradually transforming into a networked society. Technologies such as the Internet of Things, artificial intelligence, and big data will have a huge impact on human society and the built environment for living. At the same time, cities as carriers of physical space must also will change.

Modern urban planning is gradually formed in the process of social practice in order to solve urban problems. The development of science and technology provides the driving force and basic methods for the formulation and decision-making of urban planning. The emergence of big data is the emergence of the "fourth paradigm" of scientific research. It is a data-intensive scientific paradigm that unifies theory, experiment, and computational simulation. It analyzes cities through data and provides new perspectives for human cognition and scientific research⁹. The development of big data will undoubtedly have a profound impact on the development and practical application of urban planning theory. The current economic and social development is rapid, the scale of big data is growing geometrically, and new technologies are emerging in an endless stream. Whether it is in the evolution of urban planning research paradigm, or the identification of functional zoning in urban planning practice, or the study of urban spatial behavior, it is important the value and meaning of. With the support of quantitative data research, the urban form will also be transformed and upgraded to respond to the requirements of the network society.

1.3.2. Urban planning responds to the advanced needs of the network society

In the Big Data Era, the development of Internet technology has brought us into the network society. The development of future cities is not limited to people's basic needs for food, clothing, housing and transportation. It requires space optimization and service upgrades to achieve more efficient resource allocation, This also requires urban planning work to summarize and discover urban rules through calculation and analysis of these data and information. Based on these rules and trends, control and design real cities, so as to more scientifically and rationally intervene in the development process of the city, and more scientifically and reasonably intervene in the urban development process¹⁰.

The era of big data has brought unprecedented opportunities for urban planning. A large number of and multi-dimensional urban big data provides comprehensive and refined resources for urban planning research, and at the same time provides a basis for planners to grasp the operation of the city and analyze the direction of urban development. Planners should, on a certain theoretical basis, use various data and technical methods to simulate city operations, diagnose city problems, evaluate development policies, explore the inherent rules of urban development, and provide support for urban planning decisions. The current urban planning response should carefully listen to the needs of the city, citizens and the network society, conduct an objective and comprehensive analysis of urban phenomena, and make more accurate predictions for urban development. The analysis results are communicated to the government, planners, experts and scholars and urban residents through multiple media. From

⁹ Zhu, D.Q. and Wu, L.(2019)'How is the specialization of education evaluation possible in the era of big data: a fourth paradigm perspective', *Modern Distance Education Research*,31(06), p14-21.

¹⁰ Yang, J.Y. and Zheng, Y.(2020)'City: Computational Complex Organic System——Comment on "Creating Future Cities"', *International Urban Planning*, (10-05), p1-10.

independent activities to multi-party participation, the scientific nature of urban planning and related policy formulation will be improved from many aspects.

2. Exploration of Computational City Thinking Mode

2.1. The connotation of computational thinking

2.1.1. Computer Science Based on 0 and 1 Computational Thinking Expression

Computer Science is expressed through a binary computer language based on 0 and 1. Because the storage and processing of data and instructions in the computer are all done by elements such as transistors and gate circuits, these elements can actually only express two states: on and off. These are the only two things that can be truly "understood" by computers. This feature coincides with the binary concept. so binary has naturally become the basic counting method of computers. People generally use 1 to represent the "on" state of the transistor, and 0 to represent the "off" state. A series of theories and structural evolution of computers are all based on binary. With the development of computer technology, binary not only can represent values and logic, but also can represent multimedia content such as text, graphics, sound, and images¹¹.

Based on a computer language built on binary theory, computers can describe and analyze various social issues through various computer algorithms. Computer algorithms are constructed through simple rules and complex logic, describe in detail the process of how the computer transforms the input into the required output in a step by step manner. It is a detailed description of the calculation process performed on the computer. Algorithms have already played a very extensive role in computer science, prompting computer science to solve various problems through computer programs into an increasingly perfect and mature track¹².

2.1.2. Computational thinking process based on iterative procedures

Computational thinking was first proposed by Professor Jeannette M. Wing of Carnegie Mellon University. It is a series of thinking activities using computer science thinking to solve problems, system design, and understanding of human behavior¹³ (ACM Proceedings,2006.). In 2011, she updated the definition again and proposed that computational thinking includes five basic elements: algorithm, decomposition, abstraction, generalization and debugging. Computational thinking absorbs the general mathematical thinking methods used when solving problems, the general engineering thinking methods of the design and evaluation of huge complex systems in the real world, and the general scientific thinking methods of complexity, intelligence, psychology, and understanding of human behavior. Mathematical thinking focuses on the relationship between objects; logical thinking focuses on recursion; engineering thinking focuses on process and method; However, computational thinking focuses on the state of calculation (environment, constraints) and its evolution.

¹¹ Wang, Z.L.(1998)'Is 1 plus 1 equal to 2?—Talking about the application of binary system in computer', *Journal of Binzhou Education Institute*,(02), p3-5.

¹² Lu, F.(2016)'Analysis of the important role of algorithms in computer programming', *Knowledge Guide*, Issue 14, p26.

¹³ Wing, J. M.(2008) 'Computational thinking and thinking about computing', *Philosophical Transactions*, 366(1881), p3717-3725.

Figure 2. Schematic diagram of the basic process of computational thinking. Source: Painted by the author.

The basic process of computational thinking is based on an iterative process of repeated feedback. Each repetition of the process is called an "iteration", and the result of each iteration will be used as the initial value of the next iteration. Due to the fast calculation speed of the computer, through the repeated execution of the iterative relationship establishment and process control, in order to get the optimal solution to solve various problems.

Figure 3. Iterative flowchart. Source: Painted by the author.

2.2. Computational thinking model

2.2.1. The data analysis process of computational thinking

The data analysis process of computational thinking first abstracts the actual problems into mathematical problems through data collection, and then runs and solves them in the computer through the establishment of models, design algorithms and programming, and finally obtains the optimal solution to the problem. The entire data analysis process is a complete thinking logic process based on data science to solve practical problems.

Figure 4. Computational Thinking. Source: Painted by the author.

Based on the application of computational thinking, we can build systems that interact with the real world. To a certain extent, it seems to be teaching people "how to think like a computer scientist." The emergence of computers has enriched the way humans transform the world, and at the same time strengthened the meaning and function of computational thinking that originally existed in human thinking. Computational thinking is a way of thinking that chooses the right way to state the problem, or model the problem to make it easy to handle; It uses computers as a means to abstract problem characteristics, rationally filter and analyze data, use algorithms to solve problems, and establish structural models; And it can be transferred to a disciplinary thinking in solving other related problems in the later period. Therefore, the data analysis process of computational thinking is a thinking method or thinking activity based on information technology to solve problems.

2.2.2. Data thinking paradigm of computational thinking

Computational thinking is a thought process and a way of solving problems. Computational thinking can abstract, decompose and describe a problem clearly. And through abstract features, the establishment of algorithms and structural models, the solution of the problem is expressed as an information processing flow based on various data, Therefore, a typical data thinking paradigm has been formed. This paradigm of thinking is carried out in a quantitative way based on computable means.

In the era of big data, the epistemology and research paradigm of various disciplines have changed, which has promoted a new research paradigm-"data paradigm", that is different from the "knowledge paradigm" still used in traditional scientific research. Data science is mainly based on statistics, machine learning, data visualization and other domain knowledge. Data processing based on computational thinking, mainly for data processing, data calculation, data management, data analysis and data product development, and systematic research on new phenomena, theories, methods, and technologies in the big data era. The data thinking paradigm of computational thinking is based on data science. It has strong logic and will surely become the normal way of thinking for humans to recognize the world and an important means for humans to solve various problems in the future society.

2.3. Expansion and practice of computational thinking in the field of urban planning

2.3.1. Spontaneous exploration of computational city theory

With the diversification of data applications, urban planning research has shifted from traditional visits and surveys to the use of computational city to assist decision-making and judgment. Compared with traditional fragmented information, high-quantity, high-precision data is of greater value to urban planning research. Urban space based on big data is being displayed in front of people intuitively, which

has a huge impact on traditional urban planning expressions, and has also greatly promoted the exploration of computational city theories and technical methods.

In the era of big data, analyzing and researching various types of urban data will help us make more scientific predictions about urban development trends. Therefore, to a certain extent, the top-down urban planning and the bottom-up self-organized development are intertwined with each other, and they are constantly evolving with the wave of inventions and creations of new technologies. As a result, new relationships between people and cities, new urban planning concepts and trends of thought about the future of the city are produced¹⁰. Informatization, digitization and artificial intelligence technologies are affecting the organization mode of urban space, and also promoting the spontaneous exploration of emerging urban planning theories. The proposal of related emerging urban planning theories such as smart cities and digital twin cities, it has caused experts and scholars to think more about future cities and its construction model.

2.3.2. Spontaneous Practice of computational city Theory

The current development of intelligent and digital technology has brought about great changes in cities, but also gave birth to the fourth generation of urban planning and design methods characterized by human-computer interaction^{14, 15, 16}. Cities have gradually become organisms where the virtual space constructed by various big data and the physical space are integrated. Think of a city as a network group connected by different networks. It may be that urban society has become more and more digital and virtualized, or perhaps it is the analysis of the city in an environment where information is instantaneously interconnected, although they are geographically distant, and a reasonable model for thinking about how the city of the future works¹⁷.

In the digital age, urban planning should respond to the network structure, spatial organization and internal development rules of future cities, and carry out spontaneous practical activities based on computational city theory. At present, computer and artificial intelligence technologies are integrated and penetrated into complex urban networks to calculate real-time streaming big data in the operation of the city, and learn the attributes and characteristics of these data through the logic of artificial intelligence deep learning. It can also make immediate planning and control of the city to a certain extent. The construction of Xiongan New District has begun to try to construct the real physical environment of the city, a twin "digital Xiongan" was also built to assist urban governance. This makes the process of city operation and governance more like the transmission of electrons in different spaces¹⁸. Therefore, the spontaneous practice based on computational city theory can understand the complexity of the city and the rule of operation, and through appropriate methods to predict and plan the development of future cities.

¹⁴ Wu, Z.Q.(2018)'Principles and Methods of the Intelligent City Evaluation System', *Singapore: Intelligent City Evaluation System*, Chapter 7, p101-116.

¹⁵ Wang, J.G.(2018)'Digital Urban Design Based on Human-Computer Interaction——On the Fourth Generation Paradigm of Urban Design', *International Urban Planning*,33(1), p1-6.

¹⁶ Yang, J.Y. and Yuan Q.F.(2018)'Tian Baojiang, et al. Innovation and practice of the fourth generation of urban design', *Urban Planning*,42(2), p27-33.

¹⁷ Batty, M.(2018)*Inventing future cities*. MA: MIT Press.

¹⁸ Zhou, Y. and Liu C.C.(2018)'The logic and innovation of building a digital twin city in Xiongan New District', *Urban Development Research*,25(10), p60-67.

3. Computational city theory system construction

3.1. Computational city theory

3.1.1. Computational thinking-based urban complex network cognition

In the context of economic globalization and informatization, cities and regions, cities and the surrounding environment are all communicating material, energy and information all the time¹⁹. With the advancement of technology and the popularity of the Internet, the cognitive method of the complex network of the city has also been transformed into a data analysis method based on computational thinking. In the book "The New Science Cities", Professor Batty proposed to observe the city through various "flows" in the city based on the complexity theory, and to understand the method and concept of the city as a complex network system¹⁷. Complexity theory understands the system as a bottom-up hierarchical structure composed of basic components. The basic components constitute the network. Individuals and groups interact through social and economic activities in the network, and the function of the system is the manifestation of these interactions.

Figure 5. Physical space-cyber space. Source: Long Y, Mao Q. (2019). Theory and Method of City Big Data. Beijing: China Architecture& Building Press.

In the digital age, the city can be regarded as a complex network system connected by different networks. Based on computational thinking, the iterative process of analyzing and feeding back various data of the city through mathematical models such as linear equations and matrices. Maybe it's because contemporary urban society is becoming more and more digitalized, analyzing cities in a virtualized environment, reasonable ways to solve urban problems and think about how cities will develop in the future.

3.1.2. City data simulation based on complex network

Under the current background of digitalization and informatization, the city has become a complex organism in which the virtual cyber space constructed by big data and the physical space merge with each other. The complexity of urban networks is also increasing, and urban research has undergone profound changes driven by data. Before using data for urban design and urban research, we should first recognize the changes that are taking place in the city itself and the possible trends of its future evolution²⁰. The various social problems faced by cities, all can be transformed into mathematical

¹⁹ Qian, X.S.(1994) *On Geographical Science*. Hangzhou: Zhejiang Education Press.

²⁰ Long, Y.(2019) '(New) Urban Science: Using New Data, New Methods and New Technologies to Study "New" Cities', *Landscape Architecture*,7(02), p8-21.

problems solved by computers through simulation and analysis of urban data. This mode conversion under computational thinking provides new ideas and methods for solving current social problems.

City data simulation firstly identifies the city network, and secondly, through extensive acquisition and full analysis of city data, it can have a more comprehensive understanding of the complex city network based on computational thinking. On this basis, various city data are analyzed and processed through mathematical models, able to understand the city's operating rules and potential problems reflected in the data, then make relevant urban planning decisions and give feedback through the urban system. This data-based and model-based iterative process based on computational thinking can provide important support for the modernization of urban governance and the solution of social problems.

3.2. Computational city planning prototype

3.2.1. Algorithm-based computational city construction

In the context of rapid urbanization, in order to solve the problems of urban population, transportation, energy, municipal and public services, and improve urban resilience, with the support of digital technology, Based on computer algorithms to analyze and process all kinds of data to calculate city construction, it can make predictions about future city development, and provide a basis for urban planning decisions.

The essence of urban planning is to predict and respond to future cities. The planning process of computational city is an iterative process based on algorithms, through the continuous loop feedback of data analysis, to make urban planning decisions. Through the calculation and analysis of the city's multi-source big data and information, the introduction of appropriate control mechanisms, simulation, adjustment and evaluation of the city's operation process, it is possible to discover the inherent rules of the city's operation and comprehensively control the city based on the discovered laws. Thus, it is more scientific and reasonable to intervene in the development process of the city. On the basis of the completion of this process, the city will feedback the relevant planning practices made by people through big data rules and structural changes, thereby affecting people's judgment and formulation of the next cycle of urban planning¹⁰. This continuous iterative process makes people pay more attention to the real-time dynamics of the city, and visually simulates the current status and development trend of the city²¹, and then revises the city model in real time to achieve the purpose of pre-planning.

3.2.2. Outlier recognition and system evolution

Computational city construction will obtain a large amount of data from the city's complex network system, and there may be some outliers that deviate from the predicted trend. The outliers, like other data, come from the same sensor or system, it is significantly different from other data objects, making people suspect that it originated from a completely different mechanism. In order to improve the reliability of statistical analysis and the possibility of deduction, the computer will describe and identify outliers through qualitative and quantitative methods, and delete outliers or reduce their role in data analysis in the subsequent data analysis process. To increase the credibility of the analysis results. Mutation is creation. The creative event represented by outlier overturned the pre-drawn model of computational thinking, deviating from the original paradigm may lead to sudden changes in the system. The identification of outliers in urban network data can find the differences and promote the optimization and upgrading of urban network systems to a certain extent.

The recognition and system optimization of modern urban research thoughts are basically consistent with Deleuze's philosophical thoughts of difference from a philosophical point of view. Deleuze's nomadic

²¹ Cao, Y. and Zhen, F.(2015)'The overall framework of a sustainable urban spatial development model based on smart cities', *Progress in Geographical Sciences*,34(04), p430-437.

thinking is an external thinking to get rid of strict symbolic restrictions. Borrowing from Deleuze's perspective of differences, we can find that cognitive activities are the discovery and recognition of differences. In the process of recognizing and understanding the difference, information emerges and is given meaning. The tuber theory proposed later focuses more on the overall study of the information network.

3.3. The urban form of digital twins

3.3.1. The simulation and deduction of digital twin cities

Digital twin refers to the technology, process, and method of constructing digital objects that completely correspond to physical entities¹⁸. Due to the use of sensors and the real-time feedback of data, as well as the automatic instructions issued by the computing system, the time scale of urban governance is rapidly shrinking. This change has led to the rapid development of digital twin cities^{22, 23}. The concept of "digital twin city" was first put forward in the planning of Xiong'an New District. It is the digital mapping of the physical world and the formation of a visual, controllable, and manageable digital twin city by covering the entire area of urban data such as people, vehicles, objects, and space²⁴.

As a digital version of the cloned city, the digital twin city uses data such as physical models, sensor updates, operating history and other data to establish a dynamic simulation of the actual city in a virtual digital space composed of real-time data, streams and complex computing networks, thereby reflecting the city The whole life cycle process²⁵. Data exchange in the urban physical space, such as the operating status of infrastructure, the deployment of municipal resources, etc., will be transferred to the cloud platform through the IoT technology including 5G, and will be reproduced in the digital virtual twin city, and will follow the city. The changes of the entity are updated in real time. Moreover, by calculating the data information stored in the digital twin city, the behavior results of the system under a given situation can be predicted, so that the system can make independent decisions on the rules reflected by the data, which has higher flexibility and adaptability¹⁸.

3.3.2. Practice and feedback in real cities

Digital twin cities are not only a simple mapping between virtual digital space and urban material space, but also use digital management to drive the development and construction of cities. In the digital age, digital twin cities borrow digital systems and always iterate with the problems, needs and tasks in the development of urban construction. Every behavior in the urban material space will be transmitted to the digital twin city through data and signals, and the instructions of the digital twin city after development and calculation will also be transmitted to the real urban space through digital form, and interfere with the development of the city¹⁰.

The urban material space guarantees the occurrence of various behaviors and activities, The digital twin city realizes the interaction and feedback between the physical world and the virtual world, and achieves the combination of virtual test and physical innovation. Under the framework of the urban information network infrastructure, the digital twin city previews and verifies various impacts in advance

²² Liu, G., Tan X. and Wang Y.(2019)'A new paradigm of urban construction and management based on "digital twins"', *Artificial Intelligence*,(6), p58-67.

²³ BATTY, M.(2018)'Digital twins', *Environment and planning*, p1-2.

²⁴ Xu, H.(2020) 'Ideas for the development and construction of smart cities based on "digital twins"', *People's Forum· Academic Frontiers*,(08), p94-99.

²⁵ Du, M.F.(2020)'The urban information model and modern urban governance research from the perspective of digital twin cities', *China Construction Information*,(17), p54-57.

through the analysis and processing of urban data to make corresponding planning decisions. At the same time, the implementation of planning decisions can be feedback to the digital twin city through the operation of the urban material space for the next step of data analysis and new decisions. This closed-loop iterative model of "planning decision-implementation feedback-quantitative evaluation-re-planning decision-making", it can objectively reflect urban practical experience. It has changed the separation mode of planning and construction first, then operation and management. Instead, urban development and construction under dynamic planning management make urban planning more in line with the rule of urban development, and promote the transformation from top-down urban management to urban governance with multiple participation.

Figure 6. The overall framework of the digital twin city. Source: Painted by the author.

Conclusion

The development of computer technology and Internet technology, especially the comprehensive popularization of computer terminals, has formed a network world of "everything is connected to the network and computing is everywhere". With the help of the powerful computing ability of computers, computer science has formed a brand-new computational thinking paradigm through abstract problem feature, data analysis and model construction, which has created a historic opportunity for the development of all disciplines including urban planning, and greatly promoted the exploration of computational urban planning theory and planning methods.

The comprehensive popularization of computing thinking paradigm of computer discipline in the field of social life has also promoted the transformation of computational thinking in urban form, urban planning theory and planning practice in an all-round way. Under the computational thinking paradigm, the constituent elements and systems of the city can be quantitatively compiled into multi-factor functional relations, and the urban complex network system can be equivalently compiled into multidimensional mathematical equations and multidimensional matrix. With the help of various algorithms, urban evolution can be iteratively simulated to explore the internal laws and patterns of urban development. The operation of urban system under the computational thinking paradigm, on the one hand, makes full use of artificial intelligence technology to improve the systematicness of urban cognition, the scientific nature of decision-making and the human nature of service; on the other hand, with the help of system data perception and data collection ability, it acutely captures the system deviation value, and scientifically explores the potential and possibility of system optimization.

Under the computational thinking mode, urban form will present twin shapes between real cities and digital cities. The digital city full-dimensional twin real city, with the aid of computing to simulate the various possibilities of the future evolution of the city to guide the construction and operation of the real city. At the same time, the actual city practice data continues to update and optimize digital city model to achieve more efficient and scientific urban construction practices through real-time two-way interaction. In the era of big data, computational urban planning theory and urban prototype research make response to the comprehensive computational transformation of social life and urban morphology, and provide theoretical support for building a better city.

4. References

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