"Intergenerational Twins: Reflecting the Life Character of Cities

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In this paper, we focus on why and how the "transgenerational twin" maps the life characteristics of cities, review the fundamental reasons of the "transgenerational twin", summarize the development process of the "transgenerational twin", and refine the classification system of the "transgenerational twin" elements and its relationship matrix, and point out the future direction of the "transgenerational twin" and its possible contributions. It summarizes the developmental process of the "transgenerational twin", refines the classification system of the elements of the "transgenerational twin" and its relationship matrix, and points out the future direction of the "transgenerational twin" and its possible contributions. We follow that urban life has three forms: physical life, social life and digital life. The material life and social life of the city evolve iteratively, so the digital life of the city must also map the material life and social life of the city to evolve iteratively. The introduction of "twinning" from the industrial production process to urban planning and construction management should address the characteristics of iterative evolution of cities, and be combined with "time", which is a core concern in urban planning and construction management. The key to "intergenerational twinning" is to see the future of the city, and to use the future to guide the decision-making of the present; the advantage of "intergenerational twinning" is to see the history of the city, and to make a scientific basis for current and future development; the scientific significance of "intergenerational twinning" is to find the future of the city in this way. The scientific significance of "intergenerational twinning" lies in the discovery of the laws of urban development. "Intergenerational Twinning helps urban disciplines to understand the interrelationships between history, present and future, as well as the connections between the multiple elements inherent in the process of urban life formation, and gives impetus to urban development.

Keywords intergenerational twin; digital twin; urban development
Laws of development; urban extrapolation; system of elements
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The "Cross-Generational Twin City": Mapping the Life Characteristics of the City

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Abstract: This paper explores why and how the concept of "cross-generational twin city" embodies the life characteristics of the city. It provides an overview of the con- textual origins of the term, traces its developmental trajectory, establishes a classifica- tion of the term. overview of the con- textual origins of the term, traces its developmental trajectory, establishes a classifica- tion system and a relationship matrix of the elements within a "cross-generational twin city". It provides an overview of the con- textual origins of the term, traces its developmental trajectory, establishes a classifica- tion system and a relationship matrix of the elements within a "cross-generational twin city", and prospects for future research directions and potential The paper argues that urban life has three forms: material, social, and digital. The city's digital life, reflecting its material and social aspects, dynamically represents a new form of urban life. The city's digital life, reflecting its material and social aspects, dynamically represents the ongoing transformations in the material and the social worlds. The concept of "digital twin", emerging from the industrial production process, is applied to urban planning and construction management. "The concept of "digital twin", emerging from the industrial production process, is applied to urban planning and construction management. The crux of "cross-generational twin city" lies in its ability to project

future urban development and serve as a guide for future-oriented decision-making at the present time. The crux of "cross-generational twin city" lies in its ability to project future urban development and serve as a guide for future-oriented decision-making at the present. The concept deepens our understand- ing of historical development and provides a foundation for current and future devel- opment. Its scientific significance lies in its role in unveiling the laws of urban de- velopment. - It helps shed light on the interconnections among the past, present, and future, and reveals the interplay of various factors that shape urban processes. It helps shed light on the interconnections among the past, present, and future, and reveals the interplay of various factors that shape urban processes. The concept facilitates a more comprehensive understanding of cities and empowers urban development.
Keywords: Cross-Generational Twin City; digital twin; urban development laws; ur- ban evolution, element system

1 "**Transgenerational twinning**": why should urban twins be transgenerational?

1.1 Rethinking the Digital Twin City in the Perspective of Urban Life

Digital twins originated in the U.S. and have permeated from the industrial end of the world to the twin city, and while there is much controversy, there is no denying that the concept of the twin city has become widely known and spread by the public, with similar cases such as the one in the United States.

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(Project No.: 2023YFC3807505); Shanghai 2022 "Science and Technology Innovation Action Plan" Science and Technology Support Carbon Peak Carbon Neutral Special Project "Research and Demonstration of Environmental Dynamic Planning and Design for Mega Cities under the Context of Dual Carbon" ((Project No. 22dz1207800); "Urban Planning and Design" (Project No. 2023-JB- 04), a forward-looking reserve strategic research project in the field of civil engineering, water conservancy and architecture; "14th Five-Year Plan" National Key R&D Program of China. (Project No.: 2022YFC3800205); National Natural Science Foundation of China (NSFC) Cooperation Program "Research on the Development Strategy of Engineering Science and Technology in the Next 20 Years in the Field of New Generation Artificial Intelligence and Intelligent Society" (Project No.: L (Project No. L212400016).

The essence of "green city" (green city) since the United States is "sustainable city" (sustainable city), while the essence of "smart city" (smart city) is "intelligent city" (intelligent city), the common terms such as "green city" (green city) and "smart city" (smart city). The essence of "smart city" is "intelligent city", and colloquial terms such as "green city" and "smart city" are easier to communicate. The common terms "green city" and "smart city" are easier to communicate. The origins of digital twin technology date back to the 1960s, when NASA used the basic twin idea for space planning, creating physical replicas on the ground to match systems in space. The term "digital twin" was first mentioned in 1998, referring to a digital copy of actor Alan Alda's voice at① . Then in 2002, Prof. Michael Greaves of the University of Michigan proposed virtual digital representations and 3D models of physical entities for total lifecycle management of equipment, which did not use the term digital twin at the time, but clarified the meaning of digital twins. Until 2012, NASA released its technology roadmap "simulation-based systems engineering" part, the first "digital twin" (digital twins) concept and connotation. In 2015, Siemens and other companies applied digital twins to industry and developed digital twins for industrial systems. 2017-2019, Gartner included digital twins in the top 10 strategic technologies for three consecutive years. Digital twins have attracted widespread attention and high priority, and are beginning to gain applications in various industries.

The concept of the digital twin has been variously conceptualized in the urban realm

Understanding, for example, the concept of " digital twin city " was first proposed in 2017 in the planning of Xiong'an New Area, aiming to digitally map the physical world, comprehensively cover the city's data, and form a visible, controllable and manageable digital twin city[1] . In the same year, Georgia Institute of Technology proposed the concept of "smart city digital twins", which sees digital twins as an intelligent, Internet of Things (IoT) enabled, data-rich urban virtual platform for replicating and modeling changes that occur in real cities to Improve the resilience, sustainability and livability of cities[2] In 2018, China Academy of Information and Communications Technology (CAICT) proposed that the digital twin city is a digital city based on an information technology system of digital identification, automatic sensing, networked connectivity, inclusive computing, intelligent control and platform services that reproduces a digital city in digital space that matches a physical city, and performs holographic simulation, dynamic monitoring, real-time diagnostics, and real-time diagnostics and analysis on the state of the physical city entity in a real environment. Simulation, dynamic monitoring, real-time diagnosis and accurate prediction© .

However, despite the attention given to digital twins, the Department of
sub-digital businesses as a way to expand their sales platforms, academics

Then, through this concept to increase the number of published articles, expressing the dream of the city visible, controllable and manageable, but in the practice of urban management, basically "all thunder, no rain", the core problem is that the digital twin is still not able to meet the actual needs of urban planning, construction and management, which is due to the fact that the city has:

(1) Stochastic law of growth: cities are not run and built like industrial production with well-defined processes, procedures and products, but rather as a whole composed of randomly constituted systems;

(2) Law of Boundary Blurring: The internal and external systems of the city are not as clearly divisible as those of a business, and the city is unable to delineate independent and clear boundaries in terms of logistics, transportation, information exchange, economic cooperation, social lineage, and natural ecological sharing with its neighbors;

(3) Future-oriented law: urban planning and construction is future-oriented, focusing on tomorrow, not only the present, therefore, a comprehensive portrayal of the future is more important than a simple mapping of the present;

(4) The law of historical causality: In order to understand the future development of a city, it is necessary to base the development of the city on the intrinsic causality of its past development, rather than merely replicating and imitating a real system.

Based on the above four laws of the city, the portrayal of the complex system of the city is difficult to be accomplished by merely copying and imitating a real system, but requires an accurate analog rendition of the intrinsic dynamics and mechanisms of its long-term development process, which is the fatal shortcoming of the current urban digital twin.

1.2 Development of Urban Intelligent Models Offers New Possibilities for Mapping Urban Life Characteristics

Intelligent modeling techniques have been developed in the urban sector for nearly 20 years. 2004 saw the first presentation of the campus intelligent model at the Shanghai World Expo.
(CIM) concept, later expanded to city intelli- gent model, abbreviated as "CIM"[3] . CIM takes "city being" as its theoretical basis, emphasizing that digital cities should have a growth and evolution process like real cities, and realize it by introducing intelligent models in the digital city platform. CIM is based on the theory of "city being" and emphasizes that the digital city should have the process of growth and evolution like the real city, which is realized through the introduction of intelligent models in the digital city platform. After four iterations and a lot of practice, the city intelligence model now has the ability to simulate the complex elements of the city and make predictions on key urban issues. Since 2014, the introduction of Artificial Intelligence (AI) technologies has further strengthened the ability of CitySmart models to extrapolate and make predictions. For example, the use of AI algorithms to predict urban population size, land growth, and traffic flow has become a mature technology in the field of urban research. In 2016, the author proposed and developed

It has developed the theory and technology of "city planning with artificial intelligence" and formed a technical system of urban artificial intelligence diagnosis and deduction.

The introduction of AI technology pushes the CIM to a new stage, namely CIMAI (CIM+AI). Based on the city AI diagnosis and deduction technology system, this stage helps the city intelligence system to retrace the city history and deduce the city future, providing new possibilities for scientific insight into the future development of the city[4-5] .

1.3 "Intergenerational Twins". Mapping the Life Characteristics of Cities

In urban governance, local governments and functional departments are the managers and operators of urban intelligent systems. These decision makers are no longer concerned only with the identification and understanding of current problems, but are more focused on the rational prediction of the city's future development in order to formulate more scientific and precise policies. This demand for fine-grained governance will steer the city's intelligent systems in the direction of being able to predict and extrapolate the city's future direction.

Based on years of practice in the field of urban intelligence

and reflections on the needs of city governments and functional departments, combined with the joint exploration of the academia and the industry on urban intelligence modeling and digital twins, the author proposed the concept of "intergenerational twin" in 2022 (Fig. 1). This concept introduces artificial intelligence and other technologies on the basis of digital twin, and realizes the following three goals: ① Iteration of digital life of the city, i.e., the digital life continuously maps the material life and social life, realizing continuous forward iteration; © Realization of prediction of the future of the city, based on the history of the city and today's development law, to deduce and gain insight into the city's future; ③ Analysis of the city's © Analyze the city's life composition process, deeply understand the relationship between the city's history, present and future, as well as the life composition process between the inherent multi-factors, to provide support for better understanding of the city and empowering urban development.

2 The development of "transgenerational twins".

Along with the continuous breakthroughs in technology and application in the field of urban planning, the "cross-generation twin" continues to develop, and gradually integrates key technologies such as GIS, big data analytics, urban environment simulation, virtual reality, machine learning, agent modeling and image generation, and ultimately realizes the future of seeing the city. See Figure 2 and Table 1.

2.1 C1 "Seeing Now": mapping the material elements of the city

Digital twin technology was first developed in the industrial sector, the

Its main purpose is to build accurate virtual models for physical systems to achieve simulation, monitoring and optimization[6] , the application of GIS, 3D simulation modeling technology to promote the digital twin to break through the boundaries of the industry, into the field of urban management and planning, the twin technology has the potential for multi-disciplinary applications. TC 1.0 is essentially the mapping of the physical space of the city, to establish real-time connection and dynamic feedback between the physical city and the digital city, and to reflect the real information of the city through the tracking and identification of dynamic data. The tracking and identification of dynamic data reflects the real information of the city, but only the mapping of the physical space is not enough to give full play to the powerful empowerment of informationization and intelligence to urban development[3] .

"Seeing Now", the first exhibition of this developmental stage.

The application of digital twin technology in the urban domain has been demonstrated, providing an initial understanding of the physical space of the city, but with significant limitations in understanding the inner workings of urban life and assisting decision-making, among other applications.

2.2 C2 "Seeing Shape Streams": mapping of the immaterial elements of the city and their interaction with the material elements

Based on the expansion of the urban big data backplane and big data analytics, "Seeing Shaped Flows" realizes the mapping of urban flow elements, including natural flows, human flows, information flows, and energy flows, etc. This mapping capability reveals the flow patterns within the physical space of the city, and Kitchin emphasized the key role of big data in realizing smart city planning, especially in monitoring and understanding the complexity of internal flows in cities. critical role, particularly in monitoring and understanding the complexity of flows within cities. Based on the successful acquisition of building information models and 3D geographic information of the city, IoT technology is used to digitize and visualize the relevant flow elements to intelligently sense and monitor the material in the city,

[8-9]

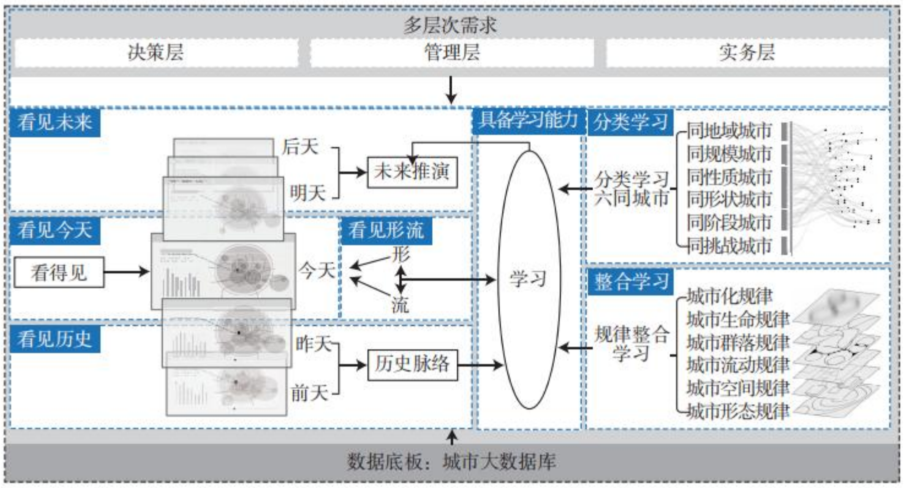

Fig.1 Conceptual illustration of the development, mutual influence, and integration of digital twins, city intelligent model, and artificial intelligence in the field of urban planning Fig.1 Iteration, mutual influence, and integration of digital twins, city intelligent model, and artificial intelligence in the field of urban planning city intelligent model, and artificial intelligence in the field of urban planning

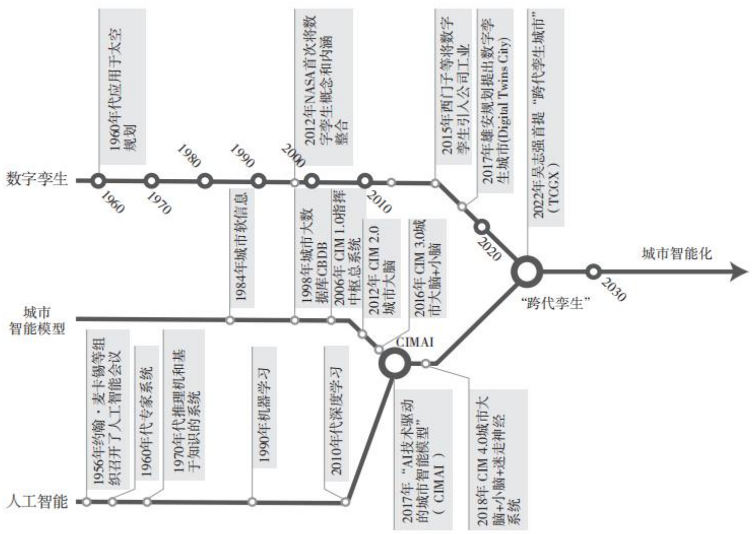

Figure 2 Schematic representation of the developmental process of "transgenerational twinning".
Fig.2 Conceptual illustration of the development process of the "Cross-Generational Twin City"

The flow of immaterial In 2008, in the post-disaster reconstruction plan for Dujiangyan, the
Relying on the urban environment simulation technology, the author and the working group simulated the natural flow of Dujiangyan, and based on the discovery of the operation law of airflow and water flow during day and night, they discovered the interaction relationship between urban activities and natural flow[10] , and reshaped the pattern of integration between the city and the mountain, the water, and the weir.

(Figure 3).In 2016, in the safety planning for flood prevention and control of Beijing's urban sub-center, the author and the working group drew on the water diversion concept of "weir" to construct a series of flood diversion systems of "Tongzhou weir", based on the multi-scenario comparison of the simulation and regulation of the regional water cycle of the sub-center, to Determine the regional flood diversion method and the diversion and storage method of each hub and flood storage area [11].

The developmental stage of "seeing flows" explains the flow patterns of immaterial elements in cities and their interaction with material elements, but it is still limited to mapping the life of today's cities, and is unable to reveal the dynamics and drivers of the urban development process, and is unable to provide a comprehensive and in-depth understanding of the developmental process.

Understand the pulse of the city's development in a deliberate way.

2.3 C3 "Seeing History": Mapping the Historical Veins of Urban Life

Based on a large amount of historical information, supported by technologies such as measurement images, virtual reality and data inversion, "intergenerational twinning" crosses generations and maps the development trajectory of the city's historical evolution to the present day. For example, analyzing the expansion time series of urban construction land data is beneficial for monitoring the dynamic change process of urban development and helps to deeply understand the driving factors of urban development[12-13] .

2011, in the planning and design of the Tsingtao Brewery.

Based on the historical gene combing of the existing historical buildings and the surrounding environment, the author and the working group reproduced the historical scene of the brewery in 1903 by relying on virtual reality and data inversion technology (Fig. 4). 2015, in the research project of "City Tree", we constructed a "City Tree" (Fig. 5) by means of an intelligent and dynamic identification of all the cities in the world through the grid with a precision of 30 m×30 m in a 40-year time span, and observed the process of urban growth intuitively. In 2015, in the "City Tree" research project, we constructed a "City Tree" (Fig. 5) by intelligently and dynamically recognizing all the cities' satellite films over a 40-year time span on a 30 m×30 m precision grid, so as to visually observe the process of urban growth and identify its growth points.[5] .

The stage of "Seeing History" expands the time vector of urban life, based on the excavation of the development pattern from the city's history to the present, and the exploration of the essence of the city's life.

Tab.1 Key breakthroughs, representative technologies, infrastructure, information data, operational security, scenario services, and the authors' geospatial practice based on "intergenerational twin" during the development of "intergenerational twin" Tab.1 key breakthroughs, representative technologies, infrastructure, information data, operational security, scenario services, and the authors' geospatial practice based on "intergenerational twin". representative technologies, infrastructure, information data, operational security, scenario services, and the authors' geospatial practice related to "Cross-Generational Twin City"

maldevelopment	C1 Seeing the present	C2 Seeing the shape of the stream	C3 Seeing History	C4 Ability to learn	C5 Classified Learning	C6 Integration of learning	C7 Seeing the future
Key breakthroughs	Mapping of the physical elements of the city	Mapping of non-physical elements of the city and their interaction with physical	Mapping of the city's historical lineage	Discovery of urban development patterns from simple	Systematic enhancement of urban development law mining, accurate	Diagnosis and optimization of urban life based on law mining	Iteration of urban life, regularity-based projection of

		elements (the main emphasis is on urban flows, including natural flows, human flows, and information flows), (Energy flow)		information mapping to knowledge extraction	mining based on multi-sample classification law		urban development trends
Representative technologies	GIS; 3D Simulation Modeling	Big data analytics; urban environment simulation	Measurement imaging; virtual reality; data inversion	Machine Learning; Apply advanced technologies such as artificial intelligence and machine learning	machine learning	machine learning	Agent models; Metacellular automata; Machine learning prediction; Parameterized generation; Image generation
infrastructure	Introducing digital technologies; realizing digital monitoring and data collection on urban infrastructure	Scale up deployment of sensing terminals; optimize infrastructure through data analysis techniques	Application of intelligent monitoring systems capable of collecting, analyzing and responding to data in real time	With large databases and implementation of cloud services	Data-sharing and teamwork between facilities	With mega data centers; Adequate cloud computing resources	Apply smart grid technology to realize the facility-to-facility intelligent collaboration
Information data	Basic repository of economic, demographic, geographic information, etc., available. Initial data management system in place.	Have a basic database of all types of data for the city; Establishment of a better data management system	Continuous age-span data are available; Initially realize the combination of data resources and application scenarios; establish and improve data management system (e.g. political, adminstrative etc)	Urban multi-source high-frequency and high-precision data collection; Initial establishment of twin city data standard system	Multi-source data classification management; Twin Cities data standards system is well developed	Multi-source data integration; with perfect data security management capabilities	Sufficient data sample size, on-demand call

Operational safety	Guaranteeing the use of digital technology for basic security measures	Applying data analytics to urban safety measures	Realization of the integration of various types of security systems to form a comprehensive security network	Intelligent security analysis and prediction using artificial intelligence and machine learning technologies	Strict enforcement of safety standards and protocols; Establishment of a regular security assessment mechanism	Continuously optimize operation and maintenance processes; improve the efficiency and speed of security response.	Formation of a highly digitalized, intelligent and sustainable business model
Scenario Services	2D map presentation; 3D modeling to load static data	Urban Mobility Element Presentation and Analysis; Meet the needs of data query, business management, statistical analysis, etc.	Single-system twin cities for different subject needs Application Expansion; Urban Development Pulse of excavations	Cross-industry twin city apps initially hit the ground running	Cross-industry twin city application integration	Cross-Industry Twin City Application Enhancement and Iteration	Each subject's prediction and mutual prediction, game deduction, balanced allocation of urban resources
The author's geodetic practice based on "intergenerational twinning".		2008 Natural flow simulation for post-disaster reconstruction planning in Dujiangyan Dujiangyan; 2016 Beijing Urban Sub-center Tongzhou Weir Rain and Flood Simulation	2011 Qingdao Brewery 1903 Historical setting reproduced; 2015 Ningbo "City Tree" 1975-2015 History brochure	2016 Functional Layout Patterns of Beijing's Urban Subcenters Study	2016 Seven Types CityGO Learning	2022 Uncovering the Functional Laws of Xiamen's Urban TOD Area	2006 Expo crowd simulation

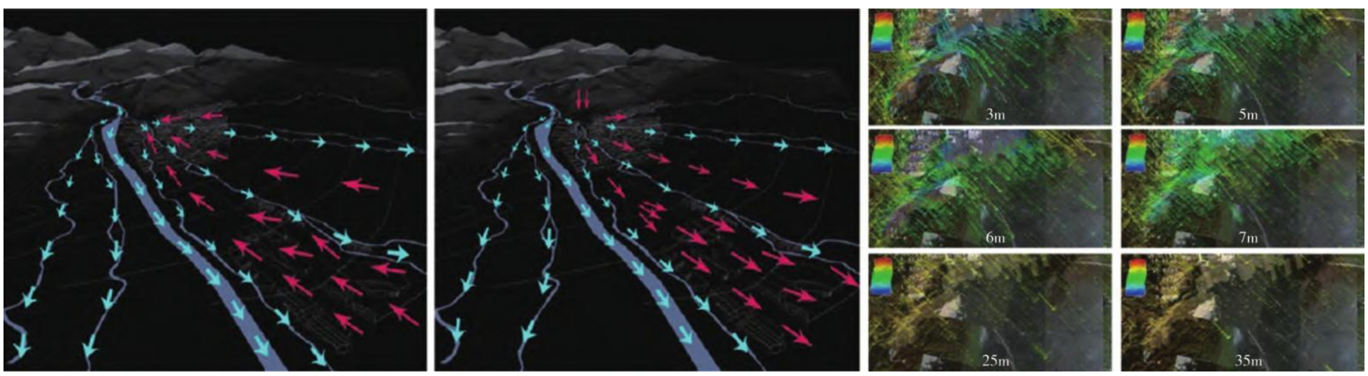

Fig. 3 Schematic of natural flow simulation for Dujiangyan post-disaster reconstruction planning
Fig.3 Conceptual illustration of natural flow simulation for the post-disaster reconstruction and planning of Dujiangyan
Source: Mapped by Dujiangyan Project Team

Fig.4 Conceptual illustration of the historical environ- ment reconstruction at Qingdao Brewery 1903
Source: Mapped by Tsingtao Brewery Project Team

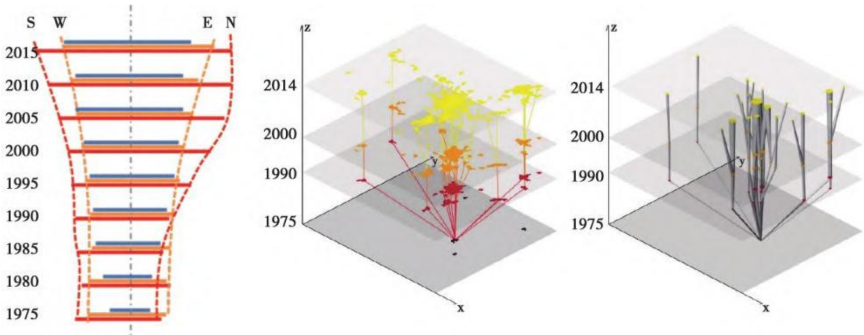

Fig.5 Conceptual illustration of the "urban tree" research in Ningbo
Source: Mapping by the Urban Tree research group.

There was a qualitative breakthrough in research, but this phase was still limited to the Simple mapping, which cannot be applied through data and algorithm integration for the purpose of solving urban problems and decision support, is unable to cope with the nonlinearity, complexity and uncertainty of urban systems.

2.4 C4 "Equipped to learn": uncovering the laws of urban life development

The advent of the big data era has brought unprecedented impacts on urban research and planning, and the technology of "Big Intelligence, Mobile and Cloud" has given a huge impetus to the development and advancement of AI-assisted urban planning methods and techniques[14-15] . With the introduction of AI technology, cities have the ability to learn, which marks a new era of data analysis and interpretation[16-17] . Beyond simple data analysis and interpretation, AI technology assists in urban information integration and knowledge formation[18] . Artificial Intelligence is capable of analyzing and interpreting large amounts of data through

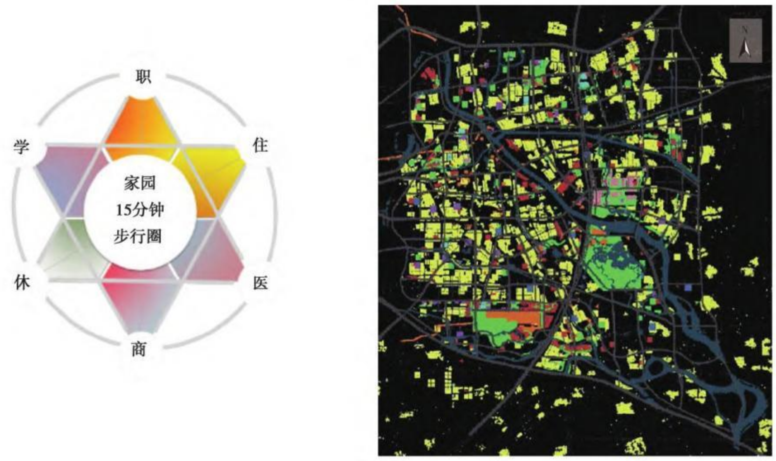

Fig. 6 Schematic study of the functional layout pattern of Beijing's urban sub-center
Fig.6 Conceptual illustration of functional layout patterns in Beijing Municipal Administrative Center
Source: Mapped by the Beijing Subcenter Project Team.

The training of the set identifies the inherent patterns, cyclical changes, and possible anomalies in urban development, thus possessing the ability to learn, and the learned and integrated knowledge can be applied to the prediction of urban development trends, thus realizing the scientific assistance to urban planning and decision-making [19].

In 2016, in the planning and design of Beijing's urban sub-center, the author and the working group divided the urban stakeholders into four parties, such as the government, planners, investors and citizens, and extracted the four parties' needs and decision-making characteristics based on deep learning technology. Aiming at the objectives of the four parties, each of them makes its own decision on the six-element functional layout model of occupation, residence, medical care, education, leisure, and commerce for the 155 km2 of the sub-center, thus constructing the decision-making function configuration model of the four parties and the six elements of[4] . See Figure 6.

"With the ability to learn" This developmental stage Based on the introduction of artificial intelligence technology to make the city has the ability to learn, but due to the city's own laws of mining and classification has not yet formed a system, the object of learning is also a lack of accurate classification and alignment.

2.5 C5 "Classification learning": systematization of the discovery of the laws of urban life development

"Classification Learning" Further focusing on the learning of key samples, AI technology import is no longer simple learning and imitation, but the formation of classification learning and law discovery capabilities, precise selection of learning objects, and the extraction of objective laws that are difficult to be discovered by human beings from complex scenarios[14] . The author and the working group propose the categorized learning object of "6 same city" for the geographic location, scale, nature, form, development stage and challenges faced by the target city. Cities with the same geographical location possess geographic proximity and are closely connected in terms of people, logistics and information flow; cities of the same scale possess similarity in terms of total population or economic output or built-up area, and are similar in terms of resource allocation and public service provision; cities of the same nature possess similar major functions of the city, and benchmarking can help to reveal how the city can give full play to its distinctive role and establish useful cooperative relationships with other cities; cities of the same form possess similar main urban functions, and benchmarking can help to reveal how the city can give full play to its unique role and establish useful cooperative relationships with other cities; and cities with the same morphology possess the following characteristics Cities of the same form have similarly shaped built-up area contours and similarities with natural patterns.

The same cities at the same stage are at the same urban life stage, and learning reveals the opportunities and problems that cities face at a particular stage of their life cycle; the same challenged cities face similar development bottlenecks and future challenges, and empirical learning can help cities to identify and implement effective solution strategies more quickly.

Using the typology technology of artificial intelligence, on the basis of the previously mentioned "city tree", the author and his team constructed seven types of CityGO learning, and summarized the budding type by counting and learning from the edges of the curve of the drawn "city tree", rickety, growing, expanding, mature, regional and declining types (Figure 7), analyzing the development vein, growth or decay trend of each type of city and its corresponding spatial pattern, in order to support the scientific decision-making of the target city.

At this developmental stage of "categorization learning," the human

Industrial Intelligence technology has enabled more accurate learning and law discovery in urban planning, and has also provided the opportunity to move from a finer level,

The transition from specific urban categorization learning to a comprehensive integration of the laws of urban development lays the groundwork.

2.6 C6 "Integrated Learning": Diagnosis and Optimization of Urban Life Based on Law Discovery

Based on the multi-sample law mining of classification learning, the "Integrated Learning" system establishes a spectrum of urban development laws, integrates and learns the multi-dimensional laws, and maps out a more global, systematic and scientific urban development model[20] . Batty's multi-agent modeling provides strong theoretical support for our integrated learning. strong theoretical support for the deeper understanding and modeling of urban spatial patterns. The purpose of integrative learning is to integrate the laws of different dimensions in a complex system in a single model, so as to obtain more global, systematic and scientific learning results[5] .

In 2016, the author and the working group in Beijing City

In the planning of the city's subcenter, based on the excavation of the subcenter's own development vein and needs, and the case study of the subcenter development of the global metropolis, we make global and systematic decision-making on the subcenter's urban population, urban density, urban industrial space, urban resources, urban transportation, spatial image, town clusters, and the construction sequence through the integration of laws and regulations (Fig. 8). 2022, in the Xiamen TOD Research Project In 2022, in the Xiamen TOD research project, through the integration and study of the functional elements and spatial relationships of 120 rail stations and their surroundings around the world, we will find out the proportion and spatial affinity of commercial, industrial, residential, innovation and transportation functions of the stations and their surroundings, and then provide a comprehensive and systematic decision for the Xiamen TOD site.

Interactively, spatial dynamics simulation is used to study urban land use and transportation policy simulation in realistic scenarios. Applications of big data and deep learning can be used to project some short-term trends, and in the future there is a need to better improve causal inference and reasoning when based on artificial intelligence and automated execution to significantly improve situational awareness, not only to be able to better predict short-term changes, but also to be able to better understand the gradual changes that the Earth system is experiencing in terms of environmental conditions and human pressures[23] .

The judgment of decision makers on the future development of the city directly determines the accuracy of their decision making, therefore, it is particularly important to predict the development trend of the city with the help of artificial intelligence for urban planning, construction and management. The introduction of urban intelligent projection model in "Seeing the Future" effectively realizes this goal and completes the essential leap to "cross-generation twin". Urban Intelligent Deduction is a technology that adopts computer modeling methods to reflect the spatial and temporal evolution of different elements of a city by reasoning and deducing their future development and change process based on specific model rules and constraints. As early as in 2006, in the intelligent model of the World Expo Park, the author and his team divided the park into 20 m×20 m spatial units for the spatial and temporal simulation of pedestrian flow.

The author and the working group have developed 12 intelligent rehearsal technologies, which use machine learning models and computer game algorithms to rehearse and dynamically optimize multi-dimensional information about the city's population, land use, environment and industrial innovation. At present, the author and the working group have completed the development of 12 intelligent deduction technologies, using machine learning models and computer game algorithms to intelligently deduce and dynamically optimize multi-dimensional information such as population, land use, environment, and industrial innovation of the city.

3 The elemental system of "intergenerational twins"

3.1 Types of elements of "intergenerational twins"

The "intergenerational twin" involves various elements that play different roles in different spaces, at different times and for different functions. A lot of practice has shown us that the failure of "intergenerational twins" to operate successfully in cities is often due to the fact that certain elements have been neglected at certain stages of the process. The compilation of these key elements and their functioning process stages is a summary of the past decade of practical work, and probably the most innovative part of this paper, i.e., it is the first time that all systems have been comprehensively compiled and summarized in their entirety, all processes, and all elements. We have thus far developed into 3 The design provides reference and support.

The developmental stage of "integrative learning" is no longer limited to learning the laws of urban development in all dimensions, but rather to a higher level of global, systematic and scientific modeling of development. The integrated learning provides a solid foundation for "intergenerational twinning".

2.7 C7 Seeing the Future: Iterations of Urban Life

Based on the series of urban development laws, the evolution of each element of the city is deduced, and then it can reflect the situation that has not yet occurred or potential problems, i.e., to see the city of tomorrow, in order to help decision makers to judge, decide, and deploy in advance. Mohammadi et al.[21] and Batty proposed to analyze the complexity of the urban system with CA models, simulate the urban dynamics through CA models, and further proposed a multi-agent model. The CA model is used to simulate the urban dynamics, and further proposed a multi-agent-based model, where each "agent" represents a participant and how they interact with the "environment" or the whole system.

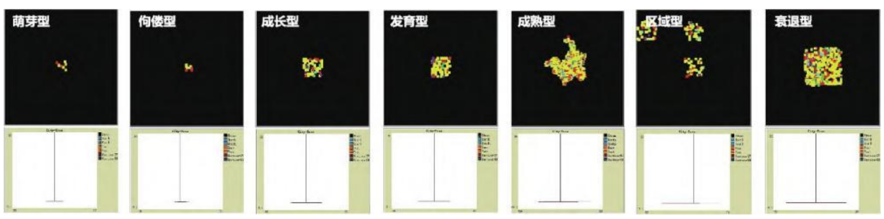

Fig. 7 Schematic of CityGO learning for seven types of cities

Fig.7 Conceptual illustration of seven CityGO's urban types

Source: Mapped by the Beijing Subcenter Project Team.

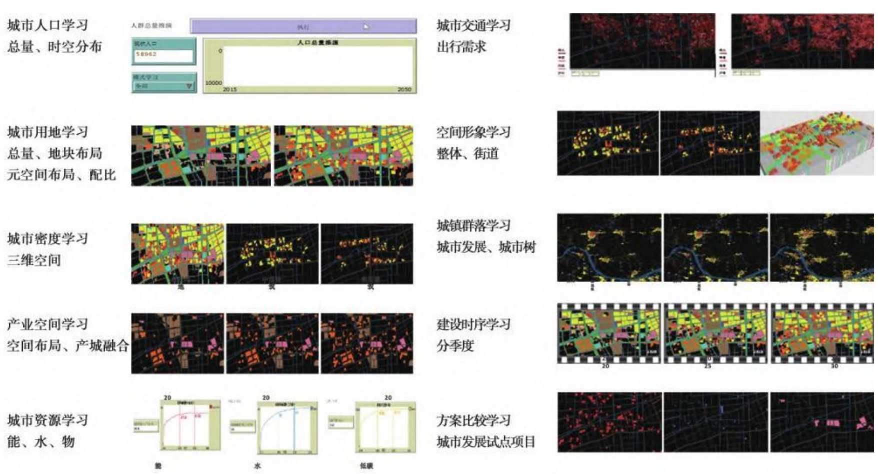

Fig. 8 Schematic illustration of urban population, land use, and other integrated learning in Beijing's urban sub-centers
Fig.8 Conceptual illustration of population, land use, and other aspects of Beijing Municipal Administrative Center
Source: Mapped by the Beijing Subcenter Project Team.

The various classification systems, respectively:

⑴ A taxonomy of substance types, including the following four categories of elements:

1. Carrier elements;
2. Digital elements;
3. Social elements;
4. Time Iteration Element.

Each category of elements contains individual sub-elements.

⑵ A taxonomy of social attributes, including the following four categories of elements:

1. User elements;
2. Constructor elements;
3. Operator Elements;
4. Investor elements.

Each category of elements contains individual sub-elements.

⑶ A taxonomy of technology processes, including the following three categories of elements:

1. Initial end elements;
2. Process end elements;
3. Terminal elements.

Each category of elements contains individual sub-elements.

3.2 "Intergenerational twins" Types of linkages between elements

The above three major categories of "intergenerational twin" can be interlocked to form two matrices to look at the reasons for the success or failure of the "intergenerational twin" in terms of the social attributes and the technological front and back end of the process of designing, constructing and operating the "intergenerational twin". According to these two perspectives, two tables are formed, which become the Matrix of Physical and Social Attribute Classification and the Matrix of Physical Attribute Classification and Technology Flow Classification of the "Intergenerational Twin" respectively. See Tables 2 and 3.

"Intergenerational Twins" Classification of Physical Attributes and Social Attributes

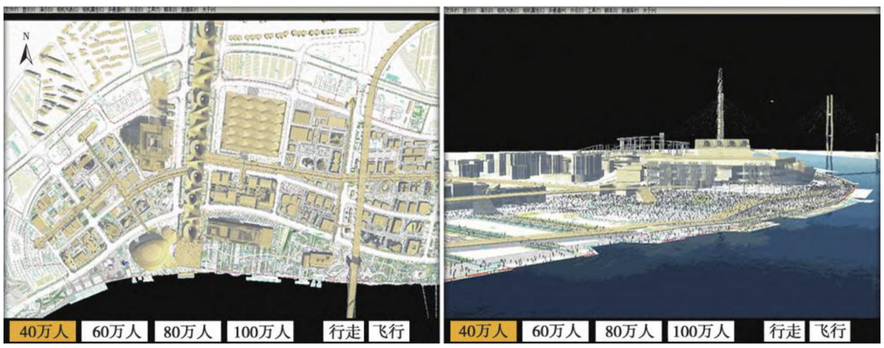

Fig. 9 Schematic simulation of pedestrian flow in Shanghai World Expo Area
Fig.9 Conceptual illustration of pedestrian traffic flow simulation in Shanghai World Expo Park
Source: Mapped by the Shanghai World Expo Project Team.

Table 2 "Intergenerational Twins" Matrix of Physical Attribute Categorization and Social Attribute Categorization
Tab.2 Matrix table of "Cross-Generational Twin City": classifications of material and social attributes

	Classification of social attributes

		User elements	constructor elements	Operator elements	Investor elements
Classification of material properties	Carrier elements	★	★★★★★	★	★★★★★
	digital element	★★★		★★★★★	★★★
	social element	★★★★★		★	★
	Time iteration element	★	★	★	★★★★★

Table 3 "Cross-generation twinning" Matrix of classification of physical attributes and classification of technological processes
Tab.3 Matrix table of "Cross-Generational Twin City": classifications of material attributes and technological pro-
cesses

		Technology Process Classification		
		primitive element	process-end element	Terminal elements
Classification of material properties	Carrier elements	★★★★★	★	
	digital element		★★★★★	
	social element		★★★	★★★★★
	Time iteration element	★	★	★

Sex classification matrix table, the three-star matrix grid is in certain social roles in certain material elements need special care, for example: the use side of the social elements of the concern; constructed side of the carrier elements of the construction of the program of the concern; the operation side of the digital elements of the collection, processing and use of the concern; the investment side of the technical experts to open up the horizons of the investment and outputs, and perhaps the twin city so far a large number of inputs, there is no way to really Perhaps the efficiency and effectiveness of urban planning, design, construction, operation and governance are missing from the vision of these investor experts, and their judgment on technology has also allowed planning experts to re-examine and truly enter the value of the use of "intergenerational twin".
"Intergenerational Twins" Material Property Classification and Technology Flow
Program categorization matrix: in the initial end, the focus on the carrier elements of the "cross-generational twin", especially the layout and quality of the data collection equipment, often directly affects the overall

Iterative updates to the system, data import at the initial end and
Sensing technology, directly affecting the "digital twin" has the ability to carry out self iteration; process end, we found that how the digital collection, processing and storage have become important, in the digital twin everyone is concerned about the final presentation, often for the processing of the data process does not get due input, including technical input, capital investment and equipment; in the terminal elements are often concerned about the use of different users, such as mobile phones or

computers, but the internal decision-making use and external display is mixed up, but the magnificent city digital twin exhibition hall is often the use of internal decision-making and external display is mixed up. In the terminal elements, often concerned about the use of different users, such as cell phone mobile use or computer use, but the internal use of decision-making and the external display is mixed up, the grandiose city digital twin showroom is often stupid, while the simple, practical is the real use of strategic decision-making.

8."Intergenerational Twin" Factor System Master Architecture

In practice, in order to comply with the individual city

The intelligent needs of economic and social development are more in line with

The decision-making of the municipal government of each city, the management needs of each business authority, as well as the daily operational requirements of each unit, each organization, and each park and community, according to the available technology, equipment and machine capabilities, the author in the city of "cross-generation twins" elements of the overall architecture of the consideration of four aspects:

(1) Systemic. The establishment of the "intergenerational twin" element system enables the "intergenerational twin" city to be constructed and applied in a systematic way. Ensure that the practical application of technologies is systematic and synergistic to better serve the sustainable development of cities.

(2) Adaptability. The selection of the "intergenerational twin" element system responds to the real needs of different cities. Different cities have their own unique economic, social and cultural characteristics, and the "intergenerational twin" element system is more flexible in its formation.

living framework to ensure that cross-generation twins can be effectively adapted to the smart needs of different cities.

(3) Decision support. The "intergenerational twin" element system provides urban decision makers with a clear framework for more informed decision support in strategy development and planning.

(4) Iterative development. The "intergenerational twin" element system helps to promote the iterative development of twin technologies and concepts through the positioning of element dimensions and twin phases, so as to better adapt to the ever-changing urban environment and technological trends.

Based on the above four considerations, the author has included the following six dimensions in structuring the total system of "intergenerational twin" elements:

D1 Infrastructure. The infrastructure dimension involves "cross-generation twins" of network infrastructure, IoT infrastructure and arithmetic infrastructure. Network infrastructure includes the critical performance and coverage of Internet, mobile and 5G networks; IoT infrastructure includes the comprehensiveness and accuracy of IoT devices, sensor networks and data collection; and arithmetic infrastructure includes data centers, cloud computing resources and processing power.

D2 Information data. The information data dimension involves "cross-generational twin" data capture, storage and management, interoperability and integration, and analysis and utilization. Data acquisition includes data diversity, frequency and quality; storage and management includes data scalability and security; interoperability and integration includes data synergy and consistency; and data analysis and utilization includes deep data mining and applications.

D3 Technology Platform. The dimension of the technology platform involves the overall architecture and functions of the "intergenerational twin". Specifically, it includes the overall technical architecture, visualization, spatial analysis and computation, simulation, virtual-reality fusion and interaction, self-learning and self-optimization, and crowdsourcing and extension applications, in order to support the needs of multiple levels and perspectives.

D4 Scenario design. The service dimensions of the scenarios are related to the actual application effect of the "cross-generation twin", service synergy and user experience. Application effectiveness includes the effect of digital applications on physical entities and spaces; service collaboration includes digital business processes and collaboration efficiency; and customer experience includes user satisfaction and interactive experience.

D5 Construction. The construction dimension involves "cross-generation twin" equipment, infrastructure and security protection, which not only guarantees the smooth and convenient use of infrastructure, information data, technology platforms and scenario design dimensions, but also, more importantly, combines the traditional systems of telecommunication, electric power, construction, decoration, interior design and materials into a complete whole.

D6 Operational safety. The operational security dimension involves the operation mode, benefit assessment, project management and security of the "cross-generation twin". The operation mode includes system operation and maintenance, equipment operation, platform operation, algorithm operation, and digital asset operation of the digital twin project; the benefit assessment includes quality acceptance, economic and social benefits, ecological benefits, and iterative optimization of multi-dimensional assessment; the project management focuses on the application of the whole-process management method and optimization and improvement of the project's progress, quality, and cost; and the safety and security involves the various aspects of planning, construction, operation, maintenance, and use of the project. Safety and security involves planning, construction, operation, maintenance and utilization.

4 "Transgenerational Twinning" Future Directions and Possible Contributions

4.1 "Personalization": meeting the individual needs of different cities

"The Intergenerational Twin is dedicated to supporting cities with more personalized and precise needs through a deep understanding of the needs of cities at different levels of decision-making, management and practice. At the decision-making level, the Intergenerational Twin provides critical macro-strategy and planning decision support to city governments through powerful intelligent services[24-25] . At the management level, the Intergenerational Twin provides real-time scheduling and full lifecycle management services to meet the needs of regional, campus and enterprise managers for economic activity and resource management. At the substantive level, the Intergenerational Twin focuses on grassroots services and operations, providing real-time, cross-business collaborative intelligent services to support the full range of operators[26] .

4.2 "New Technology Penetration": a smart iteration to gradually and continuously improve urban response

In the future, "intergenerational twin" will deeply integrate edge computing, IoT and 5G communication technologies, and deeply integrate cutting-edge technologies with city management[27-28] . This deep integration not only improves the real-time data processing and feedback capability of city management, but also helps build a city response mechanism with higher intelligence and agility. Such technological integration will make urban planning and decision-making more accurate and timely, and will help cities respond more effectively to dynamic changes, laying a solid foundation for the sustainable development of cities in the future[16, 29] .

4.3 "Adaptive Learning": Driving AI-led Digital Intelligence in Cities

The future of urban planning will rely on the development of a new generation of AI technology to develop a completely new approach to urban perception, urban awareness, urban analysis, urban simulation and urban decision-making.

The foundation may[30-31] . The future of urban planning will depend on the development of a new generation of AI technologies. In this context, the "intergenerational twin" will become an urban intelligence system with excellent self-learning and self-adaptive capabilities. This will not only enable it to better see the future of the city and lead the management of the city today and tomorrow, but also enable it to intervene in the city in a less costly and efficient way[32] . The "intergenerational twin" will also simulate the effects of interventions in real time, providing a continuous, adaptive and forward-looking research framework for urban and rural planning. This comprehensive upgrade will greatly enhance the value and impact of the "intergenerational twin" in practice, and inject more innovation into the future of urban planning [33-34].

4.4 "The Real and the Virtual": Creating a New Life for the City's Endlessness

The development of "intergenerational twins" will lead to a fusion of the real and the virtual city forms[35] . The relationship between physical and virtual cities will be mutually cooperative, with the physical city providing the virtual city with the ability to provide real services, and the virtual city bringing new and innovative possibilities to the physical city[36] . This mutual promotion of virtual and real cities will form a spiral development pattern and realize the innovative development of urban life forms.

4.5 "Crowd Brain Structure": Building a New Era of Intelligent Urban Clusters

"Intergenerational Twinning" will coordinate the needs of urban decision makers, business leaders and corporate leaders, professional scholars, street committees and neighborhood committees, urban and rural people, and the media among all urban decision makers, to build a three-dimensional, multi-level, multi-brain cluster intelligence architecture towards the intelligentization of urban clusters.

5 concluding remarks

The urban twin must evolve into a "cross-generational twin". In the urban environment, the industrial twin especially needs to have cross-generation characteristics, otherwise it will not be able to give full play to the essential role of urban digital intelligence, see the future of the city and see the history of the city, and will not be able to produce more fundamental effects and contributions to the solution of urban problems. Since 2004, the author has been accumulating, breaking through and innovating in the field of urban intelligence, which involves data mining, law discovery, future projection and power mechanism analysis. The author expects and invites more scholars to participate in the research of the "cross-generation twin" proposition, and jointly promote the expansion and exploration of theories, technical models and application scenarios.

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