

Smart city based on digital twins

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Abstract

Digital twins are considered to be a new starting point for today's smart city construction. This paper defines the concepts of digital twins and digital twin cities, discusses the relationship between digital twins and smart cities, analyzes the characteristics of smart cities based on digital twins, and focuses on the five main applications of smart cities based on digital twins. Finally, we discuss the future development of smart cities based on digital twins.

Keywords: Digital twin, Smart city, Digital city, Big data, AI

1 Digital twins and smart city

It is generally believed that the “Digital Twin” is a simulation process that makes full use of physical models, sensors, historical data of operation, etc. to integrate information of multi-discipline, multi-physical quantities, multi-scale, and multi-probability. It serves as a simulation process for physical products in virtual space. The mirror body reflects the whole life cycle process of the corresponding physical entity product (Yu et al. 2017). In fact, there are currently many different understandings of the concept of digital twins, and a consensus definition has not yet been formed. However, it is generally believed that physical entities, virtual models, data, connections and services are the core elements of digital twins (Tao et al. 2020). The essence of digital twins is a bi-directional mapping relationship that exists between physical space and virtual space. This bi-directional mapping is different from the unidirectional mapping, which only maps data from physical entities to digital objects. The latter also is called a digital shadow (Kritzinger et al. 2018; Zheng et al. 2019), that is, “a change in state of the physical object leads to a change in the digital object, but not vice versa.” (Kritzinger et al. 2018). However, digital twins enable virtual objects to control physical entities without human intervention (Enders and Hoßbach 2019), which is a feature that digital shadows do not have. As a key way to realize the

bidirectional mapping, dynamic interaction, and real-time connection between the virtual and the real, the digital twin can map the physical entities and attributes, structure, state, performance, function and behavior of systems to the virtual world (Tao and Qi 2019), forming a high-fidelity dynamic multidimensional, multi-scale, multi-physical quantity model, which will provide an effective way for observing, recognizing, understanding, controlling and transforming the physical world (Tao et al. 2019).

Digital twins first appeared and played a role in industries of product and manufacturing design, and later emerged in industries such as aerospace (Liu et al. 2020), automation (Talkhestani et al. 2018), shipbuilding (Mondoro and Grisso 2019), healthcare (Jimenez et al. 2020) and energy (Enders and Hoßbach 2019; O'Dwyer et al. 2020). In recent years, with the rapid development of technologies and industries such as the Internet of Things (IoT) (Kaur et al. 2020), big data (Tao et al. 2018), cloud computing (Khatib et al. 2019) and artificial intelligence (AI) (Kharchenko et al. 2020), the construction basis of smart city has gradually evolved from the original static 3D modeling level towards the digital twin level that combines dynamic digital technology and static 3D model (Yan et al. 2019), which forms a new concept that digital twin city assists smart city construction. Obviously, the digital twin city is a wide application of the digital twin concept at the city level. It aims at constructing a complex giant system between the physical world and the virtual space that can map each other and interact with each other in both directions. It can

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match the physical city to the corresponded “twin city”, forming a pattern of coexistence of both and integration of physical cities in the physical dimension and digital cities in the information dimension. The construction of a digital twin city requires a data foundation and a technical foundation. The data foundation refers to the massive urban big data that is continuously generated every day from various sensors and cameras everywhere in the city, as well as the digital subsystems successively built by the municipal management departments. Technical foundation refers to relevant technologies such as the IoT, cloud computing, big data, and AI, including 5G (Li et al. 2017). In a digital twin city, the data of operating status of infrastructure, the deployment of municipal resources, and the flow of people, logistics and vehicles will be collected through sensors, cameras, and various digital subsystems. With technologies including 5G delivering them to the cloud and the city government, the city will be more efficient.

The construction of digital twin cities will trigger great innovations in urban intelligent planning, management and services, and become a “new starting point” for the construction of smart cities. This will help achieve the goal of visualization of all-element information of the city and the intelligentization of city planning, management and services. The digital twin city is not only the goal of a digital city, but also a key element of a smart city. It is an important facility and basic capability that enable the city to realize smartness. It is also a milestone in the transformation of urban informatization from qualitative change to quantitative change driven by technology, which provides the construction of smart cities more room for innovation.

2 Characteristics of smart cities based on digital twins

From different perspectives, there are different understandings of the concept of digital twin. Tao et al. (Fei et al., 2020) starts from different dimensions, summarizes and analyzes the current several understandings of digital twin, and proposes the ideal characteristics of digital twins in the model dimension, data dimension, connection dimension, service/function dimension and physical dimension (as shown in Table 1), which is the “five-dimensional model” of digital twin. Tao et al. pointed out that because digital twins at different stages exhibit different characteristics, the understanding and practice of digital twins cannot be separated from specific objects, specific applications and specific needs. Therefore, the actual application does not necessarily require the established “digital twin” to have all the ideal characteristics, and it is acceptable for it to meet the specific needs of users (Tao et al. 2020). As an extension of the digital twin concept in the urban field, the digital twin city also exhibits specific characteristics based on the ideal characteristics of the digital twin.

Combined with the existing discussion, digital twin cities have four major characteristics: Accurate Mapping, Virtual-real Interaction, Software Definition, and Intelligent Feedback. Accurate mapping means that the digital twin city realizes comprehensive digital modeling of urban roads, bridges, manhole covers, lamp covers, buildings and other infrastructures by arranging sensors on the air, ground, underground, and river levels in the physical city, so as to fully perceive and dynamically monitor the city’s operating status, and finally form the accurate information expression and mapping of the virtual city to the physical city in the information dimension. Virtual-real interaction means that all kinds of

Table 1 Different understandings of “digital twin”

Part of Understanding	Ideal Characteristics	Digital Twin Cities	Dimensions
1 a. Digital twins are 3D models b. Digital twins are copies of physical entities c. Digital twins are virtual prototypes	Multi-dimensional/multi-space-time/multiscale Dynamic/evolutive/interactive High fidelity/ Highly reliable/high-precision	Accurate Mapping	Model
2 a. Digital twins are data/big data b. Digital twins are PLM (Product Lifecycle Management) c. Digital twins are digital thread d. Digital twins are digital shadow	Total factor/all-service/ complete flow scheme/full life circle Virtual-real fusion/ multi-source fusion/heterogeneous integration Real-time update/real-time interact/real-time respond		Data
3 a. Digital twins are Physical union platform b. Digital twins are industrial Internet platforms	Bi-directional connection/interaction/driving Cross-agreement/interface/platform	Virtual-real Interaction	Connection
4 a. Digital twins are simulation b. Digital twins are virtual verification c. Digital twins are visualization	Model driven + Data driven Simulation verification/visualization/control/predict/optimize	Software Definition	Services/ Functions
5 a. Digital twins are pure digital representation or virtual bodies b. Digital twins are irrelevant to entities	models vary from object to object/data vary by feature/services and functions vary according to needs	Intelligent Feedback	Physical

“traces”, such as traces of people, logistics and vehicles that can be observed in the physical city, can be searched in the virtual city once they are generated. Software definition means that the twin cities establish a corresponding virtual model based on the physical city, and simulate the behavior of urban people, events and objects in the virtual space by means of software platforms. Intelligent feedback refers to the intelligent early warning of possible adverse effects, conflicts and potential dangers of the city through planning and design, simulation, etc. on the digital twin city, and the function of providing reasonable and feasible countermeasures. On the basis of the digital twin city, the integration of the IoT, cloud computing, big data, AI and other new-generation IT technologies can guide and optimize the planning and management of physical cities, which will improve the supply of citizens’ services and assist more in the construction of smart cities. Hereinafter, we will use five typical applications to introduce how smart cities based on digital twins serve the actual operation of cities.

3 Applications of smart cities based on digital twins

3.1 Smart city operation brain

Based on the digital twin city, a Smart City Operation Brain (SCOB) can be established, and the city officials will take the lead to establish a Smart City Operation Center (SCOC) and appoint a Chief Operating Officer (COO) to take the charge. Figure 1 shows the complete management structure of the SCOB based on the digital twin city. The SCOC is under the jurisdiction of the COO, and between them the Chief Information Officer

(CIO) Joint Conference Committee is responsible for coordination and management. SCOC manages four major sectors for the urban information, including Urban IT Operation and Maintenance Center, Big Data Center, Urban Operation Monitoring and Command Center, and Smart Service Center (including open data platforms, data marts, and other companies). The main functions of SCOB include (1) Participating in and reviewing the top-level design of the city; (2) Planning and reviewing the overall goals, frameworks, tasks, operation and management mechanisms of the informatization development of various industries; (3) Formulating relevant policies, regulations and standards; (4) Responsible for the integration and sharing of urban information resources; (5) Monitoring city operation, multi-departmental coordination and command; (6) Promoting the formation of the system of social-oriented big data open applications, services and transactions.

The Public Information Cloud Service Platform is the infrastructure part of the SCOB. Once the Public Information Cloud Service Platform is established can the office of SCOB start to operate, and the officials can just use the “applications” of the platform to take the charge of management of the smart city. Figure 2 shows the structure of the Public Information Cloud Service Platform. The platform is composed of infrastructure layer, software development and operation platform layer, and application layer. The platform uses infrastructure such as servers, networks, and sensor equipment to acquire data, and uses cloud infrastructure, data, platforms and software as services, and finally achieves the applications of cloud service platforms in various fields such as smart urban management, smart public security, and smart

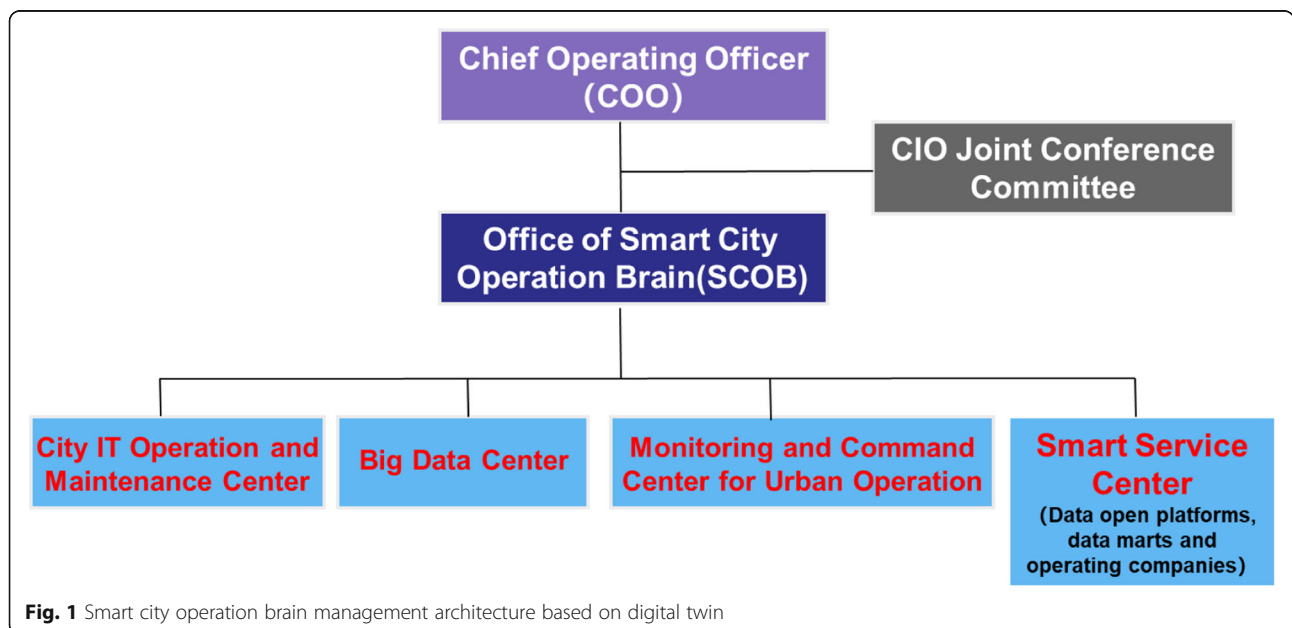


Fig. 1 Smart city operation brain management architecture based on digital twin

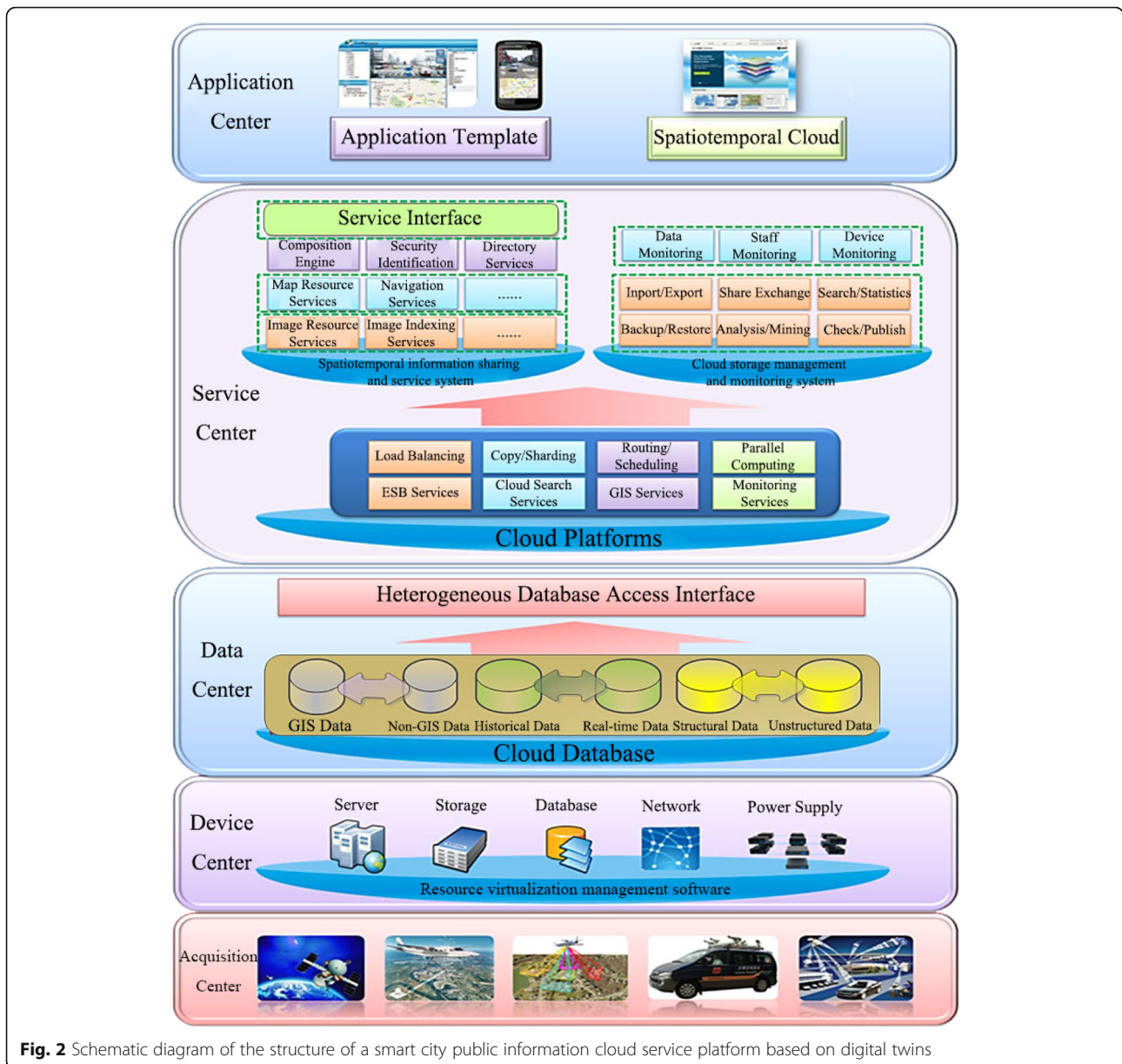


Fig. 2 Schematic diagram of the structure of a smart city public information cloud service platform based on digital twins

tourism. The platform can create an ecological chain of data collecting, processing, storing, cleaning, mining, applying, and feedback. The smart city operation center based on the digital twin city is the heart of the smart city. It is the resource pool of urban big data and the hub of the urban IoT. It commands and monitors the operation of the city, and comprehensively obtain the city’s operation data, so as to realize the efficient coordination and emergency response capabilities of cross-departmental and cross-regional systems.

Figure 3 is a schematic diagram of the structure of a smart city operation brain based on a digital twin city. Based on the smart city operation brain, a multi-portal integrated city command and emergency

center can be built with the integration of the data from the cloud data center and the digital subsystems of various departments. The center also uses basic data analysis components such as multi-dimensional analysis and data mining, and analysis applications such as IoT perception and real-time operation monitoring. This center can reduce the cost of urban informatization projects and its maintenance, minimize the cost of government affairs, and improve urban efficiency.

3.2 Smart grid digital twin services

The Smart Grid Digital Twin is a simulation process with multiple physical quantities, multiple temporal and

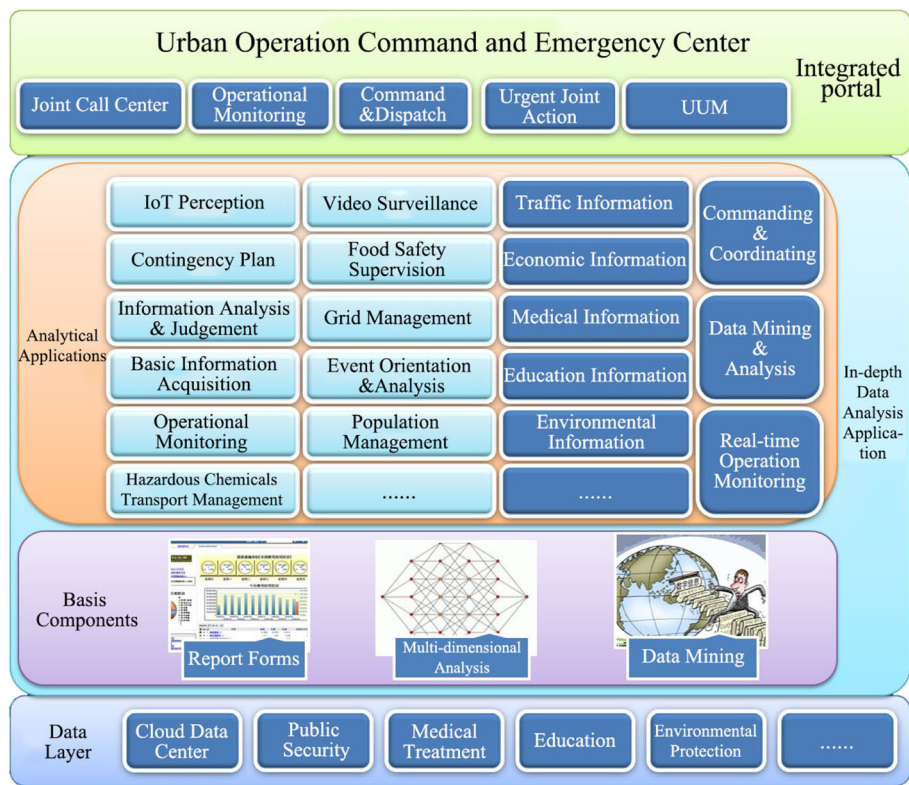


Fig. 3 Schematic diagram of the smart city operation brain based on digital twins. (UUM: Unified Users Management)

spatial scales and multiple probabilities, which makes full use of the physical model, online measurement data and historical operation data of the power system, and integrates multi-disciplinary knowledge such as electricity, computers, communications, climate, and economics. It reflects the entire life cycle process of the smart grid by mapping it in the virtual space. Due to the increasing demand for electricity by humans, the scale of

power grid transmission lines is expanding year by year (Fig. 4), coupled with the frequent occurrence of natural disasters and the deterioration of the equipment operating environment, resulting in increased pressure on power grid line inspections. Current line inspections mainly rely on manual ways. However, this method is not only inefficient, but also has inspection blind spots, which gradually cannot fully meet the needs of power

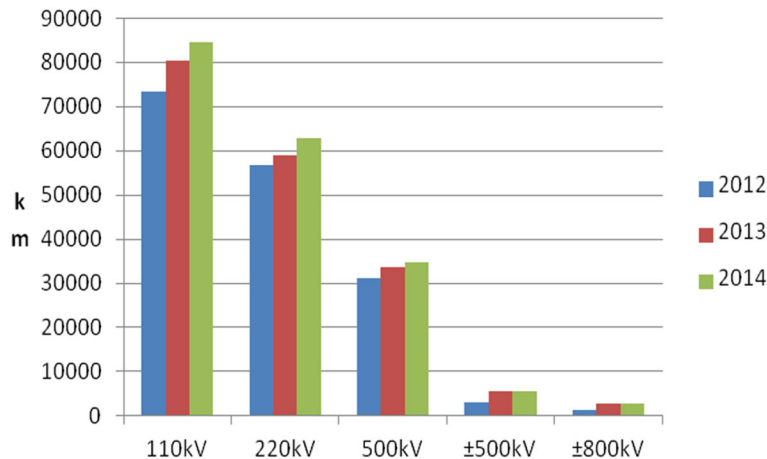


Fig. 4 Growth of various voltage classes in China from 2012 to 2014

grid inspections (Fig. 5). Modern power grids urgently need to establish a safe, efficient and intelligent inspection mode.

Based on the digital twin smart grid technology, we can develop a technique of on-line, real-time detection of insulator damage and AI on-line calculation of tree barrier safety distance (Fig. 6). This technique can realize real-time inspection, fault interpretation, and report the output, thereby greatly reducing labor intensity. In addition, relying on this technique, a software and hardware integrated system based on power corridor multi-element precise positioning, identification and modeling, and 3D spatial relationship calculation model can also be established, which can be used to solve the problems of power corridor security risk positioning and its early warning. At present, the technique has reached 15 provinces, cities and regions in China, with an inspection line of about 20,000 km and an inspection mileage of more than 50,000 km, bringing economic benefits of more than 200 million yuan.

3.3 Smart city traffic brain

The Smart City Traffic Brain is another application of smart city based on digital twin. Hundreds of millions of big data on travel trajectory are generated in cities every day from mobile phones, surveillance camera videos, taxis, indoor positioning systems, buses and subways, and also mobile apps. Relying on technologies such as holographic perception, time-space analysis, and data mining, the Wuhan Road Traffic Smart Emergency System (Fig. 7) is developed, which is an important part of Wuhan Smart City Traffic Brain. The system is designed to deeply integrate multi-network resources and real-time dynamic traffic information, while connecting various emergency platform resources such as city alarm system, the police, road condition system, accident

emergency system and traffic video system, and displaying them on the same interface. The Wuhan Road Traffic Smart Emergency System realizes traffic big data management based on real-time traffic data flow. It developed an congestion index evaluation algorithm which combines historical congestion data, traffic data, vehicle speed data and other information to realize functions such as (a) accurate evaluation of road congestion levels; (b)real-time ranking of road congestion; (c) comparative analysis between historical congestion and real-time congestion. The system also provides functions such as video verification, major event security, real-time scheduling and navigation, and congestion event playback. All these functions provide a decision-making mechanism to help traffic departments to relieve and clear traffic congestion with the benefit of smart traffic cloud and GIS computation.

3.4 Smart city public epidemic services

A Smart City Public Epidemic Service System can be built based on components of the data cloud platform, analysis system, response system and user terminals (Li et al. 2020) (Fig. 8). The patient spatiotemporal data is formed by fusion of the patient information provided by the hospital information system of major hospitals and the patient's spatiotemporal trajectory data provided by the communication operator, which is stored in the patient spatiotemporal database. This database can be connected to the spatiotemporal data cloud platform and connected to the epidemic big data analysis system. The analysis system uses spatiotemporal proximity analysis, AI analysis and other technologies to determine the occurrence of the epidemic and determine the people in close contact, and the results will be transmitted to the response system. The response system connects with government departments, employers and individual

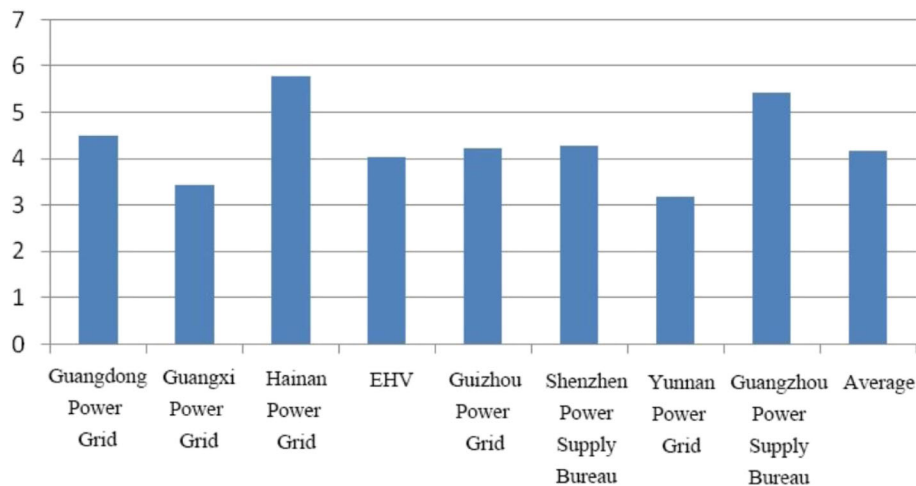


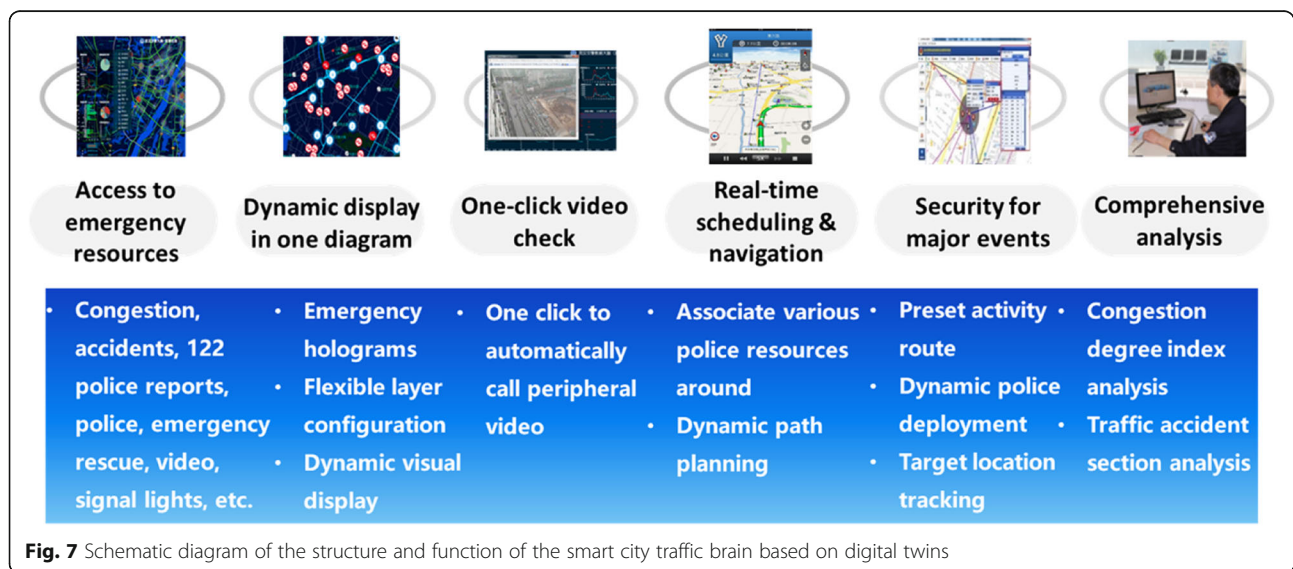
Fig. 5 Staffing situation of State Grid Branch in 100 km

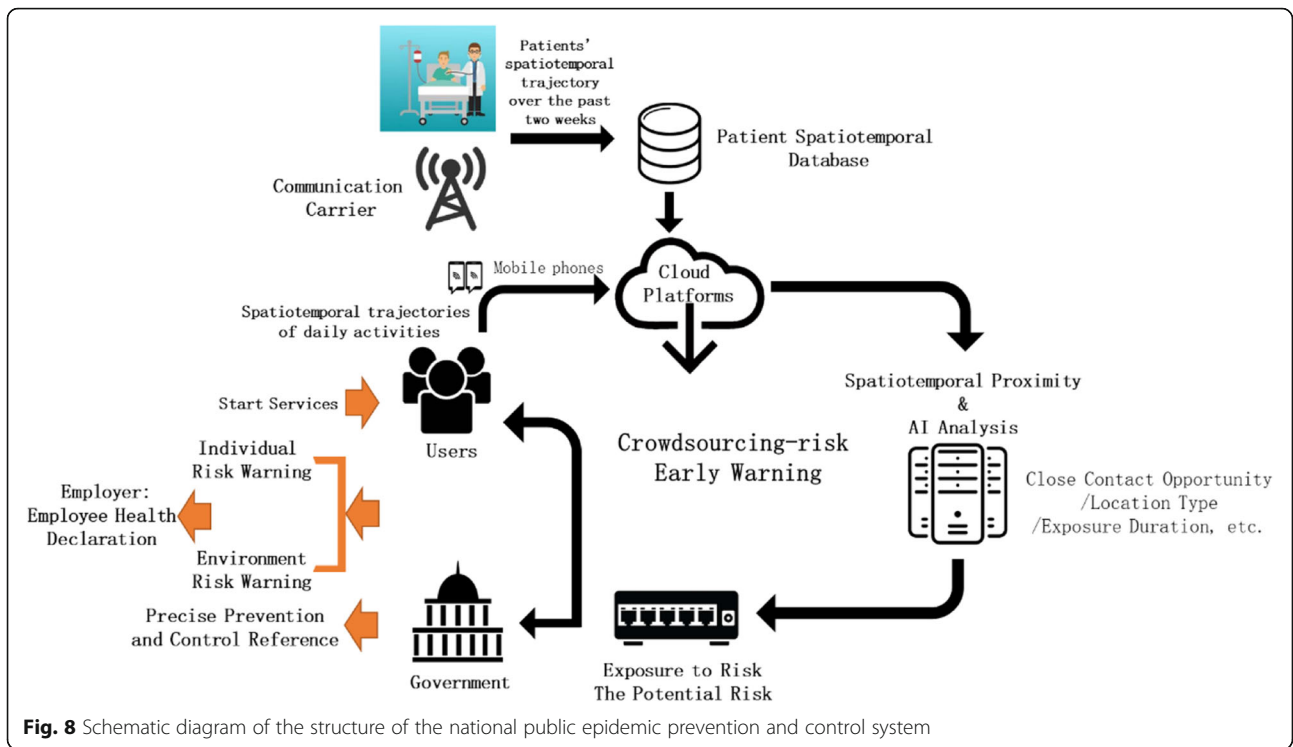


users, provides the government with a reference for epidemic prevention and control, the employers with a reference for employees' health condition declarations, and individuals with information services for self-isolation and protection.

At present, the use of space-time big data and AI location intelligence technology to trace back the historical trajectory of personnel can realize functions such as finding close contacts, predicting high-risk areas, and assisting in the analysis of virus transmission dynamics models (Fig. 9). Specifically:

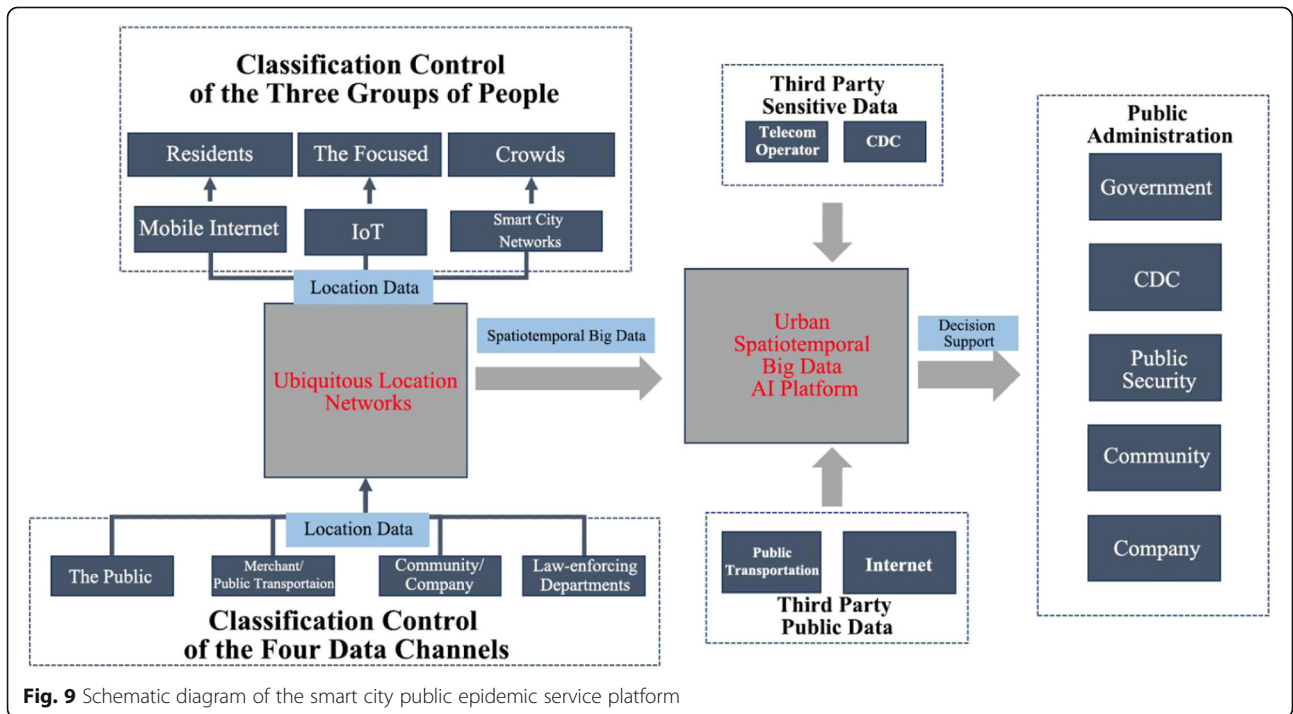
1. Detailed analysis of "disease traceability". Based on population information of visiting cities from high-risk areas, population distribution heat maps, and key epidemic areas, combined with the locations of confirmed cases and the locations of communities where confirmed cases have occurred, the function of analyzing the degree of epidemic exposure risk in different areas can be realized. The system can also analyze the daily data of flow of people to monitor the status of the population in severe areas and the status of severe populations.





2. “Risk warning” precise reminder. The system can analyze the risk levels of different areas according to the disease transmission model, especially high-risk areas. For people entering the area, the system can provide real-time mobile phone warning services to

remind citizens to take protective measures or change lanes to avoid entering the area (exposure warning). The system can also provide risk early warning services based on the contact history of the confirmed cases, which is also decision-making



basis for the disease control management department to accurately determine the risk population and improve the efficiency of disease control (contact early warning).

3. Global integrated management of “Grid Prevention and Control”. The system displays the heat map of confirmed cases of the epidemic from different levels such as the country, provinces, cities, districts, streets and communities, and displays the spread of the epidemic nationwide. The system flexibly configures dynamic data, and analyzes the flow of key populations in various provinces, cities, and districts through multiple-dimensional charts to achieve real-time monitoring of real-time epidemic situation.
4. “Resumption of work and production” approval control. The system establishes a company’s return to work declaration and review process, which is used to fill in the employees’ health status data and supervise the implementation of the company’s epidemic prevention measures. At the same time, the system can intelligently analyze the abnormal situation of the enterprise and provide real-time early warning services to assist the integration of resumption of work and epidemic prevention management.

3.5 Flood monitoring and flood situation services

In the full life cycle of flood disaster’s normalized monitoring and forecasting before disasters, dynamic monitoring and analysis during disasters, and assessment and reconstruction after disasters, an application scenario for real-time urban flood simulation and think tank research and judgment services can be established using digital twin technology, which thereby adding service functions to the construction of smart cities (Fig. 10). The smart city flood monitoring and service system based on the digital twin mainly covers three parts, namely, the normalized and dynamic big data monitoring of flood, the flood knowledge map and the flood service application. Flood big data monitoring refers to the monitoring method of real-time collection of flood disasters and flood big data from the urban and watershed scales in the context of the IoT, combined with the real-time monitoring technology of the integration of space, air and earth. The main point is to collect water conditions in rivers and lakes, rain conditions in urban meteorological stations and dynamic trajectories of people and vehicles from monitoring and collection equipment such as ground sensors. This can be realized based on satellite remote sensing technology in large-scale air and sky scenarios to monitor cloud and rain water volume, lake water volume and water level changes of rivers and reservoirs in the upper and lower basins. Figure 11 shows

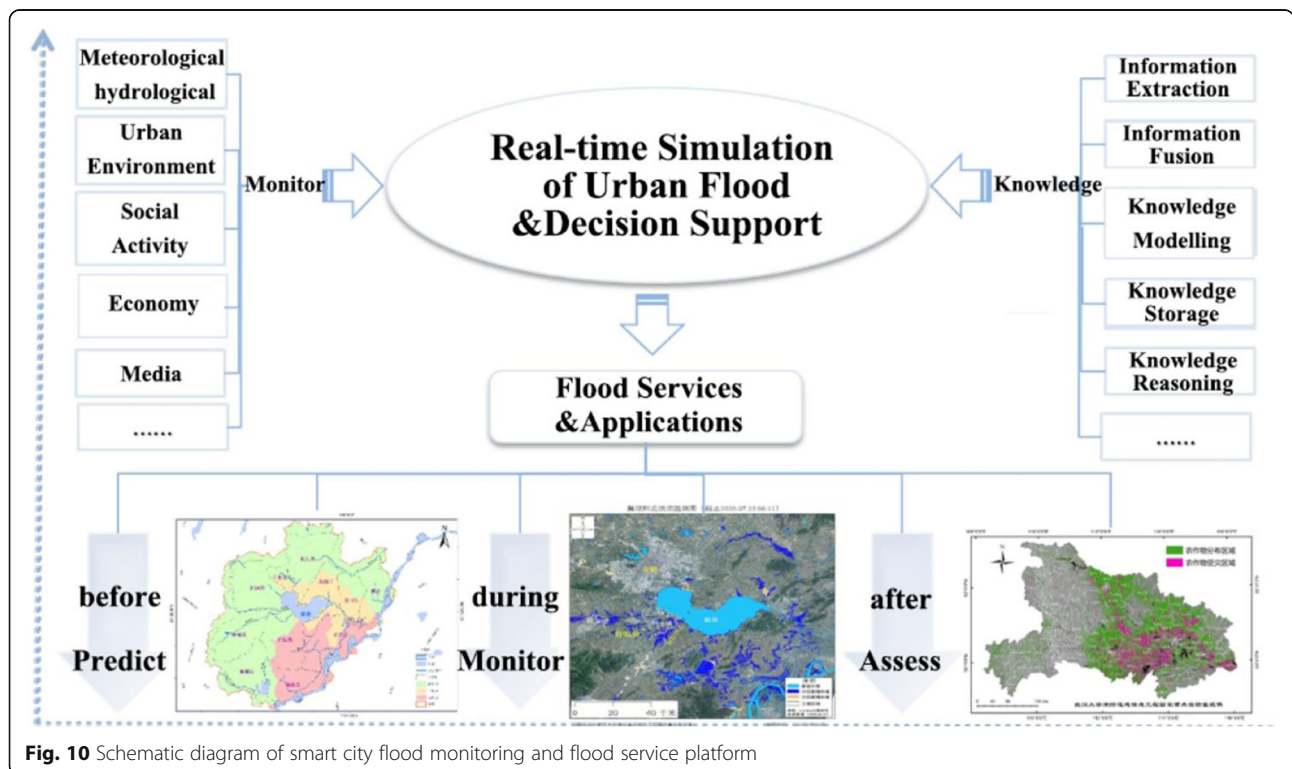


Fig. 10 Schematic diagram of smart city flood monitoring and flood service platform

as an example, which used the Gaofen-3 satellite image on July 13, 20, and 21, 2020 and the Radarsat2 image on July 24, 2020 to monitor the Wangjiaba and nearby waters before and after the gate was opened. It can be seen that on July 13, the water area of the Mengwa flood storage area before the background flood storage was about 10.19% (the blue area); On July 20, about 6:30 pm (about 10 h after the gate was opened), the Mengwa flood storage water area of the district increased to 30.68%, and the newly added water body was an orange area; On July 21, at about 5:30 pm (about 33 h after the gate was opened), the flooded area increased to 59.19%, and the new water body was a red area; As of 09:54 on July 24 (4 days after the gate was opened), the submerged area increased to 80.31%, and the newly added water body was a deep red area. At the same time, a system based on the service also regularly captures public opinion information. Figure 12 is an example, which shows the results of sentiment tendency analysis. It can be seen that the public is positive about flood control, and the positive emotions marked with warm colors are obviously more than the negative emotions marked with cool colors..

The construction of a flood knowledge map is to establish a flood big data knowledge map through big data analysis and AI technology, which will help infer knowledge and discover knowledge based on dynamic monitoring of flood disasters and flood big data. Based on normalized and dynamic flood monitoring and flood knowledge map, a smart city flood service application can be provided, which includes real-time simulation of flood monitoring big data in urban scenes. Combining

flood knowledge analysis, knowledge mining, modelling, and flood disaster prediction technologies, flood-related knowledge can be visualized in the entire life cycle of urban flood disasters, which will then help to provide services for urban flood control management.

4 Conclusions

A smart city is based on the integration of the real world and the digital world established by the digital city, the IoT and cloud computing to realize the perception, control and intelligent services of people and things, while the digital twin city is undoubtedly a new starting point for the construction of modern smart cities. Smart cities based on digital twins have broad prospects for economic transformation, urban smart management and public smart services, so that man and nature can develop more coordinately. The realization of smart cities requires the construction of more complete spatial information infrastructure to ensure that various smart city applications can be used well and affordable. The big data problem of smart cities brings new opportunities and challenges. It is necessary to do a good job in technological innovation and research in order to promote the development of the digital service industry, better realize the various smart applications of Internet + smart city, and develop the digital economy. The construction of smart city is a leading project. It is necessary to do a top-level design and overall planning according to the characteristics of each city, and establish a smart city operation center and operation brain to make the city smart. Only by doing a good job in the design,

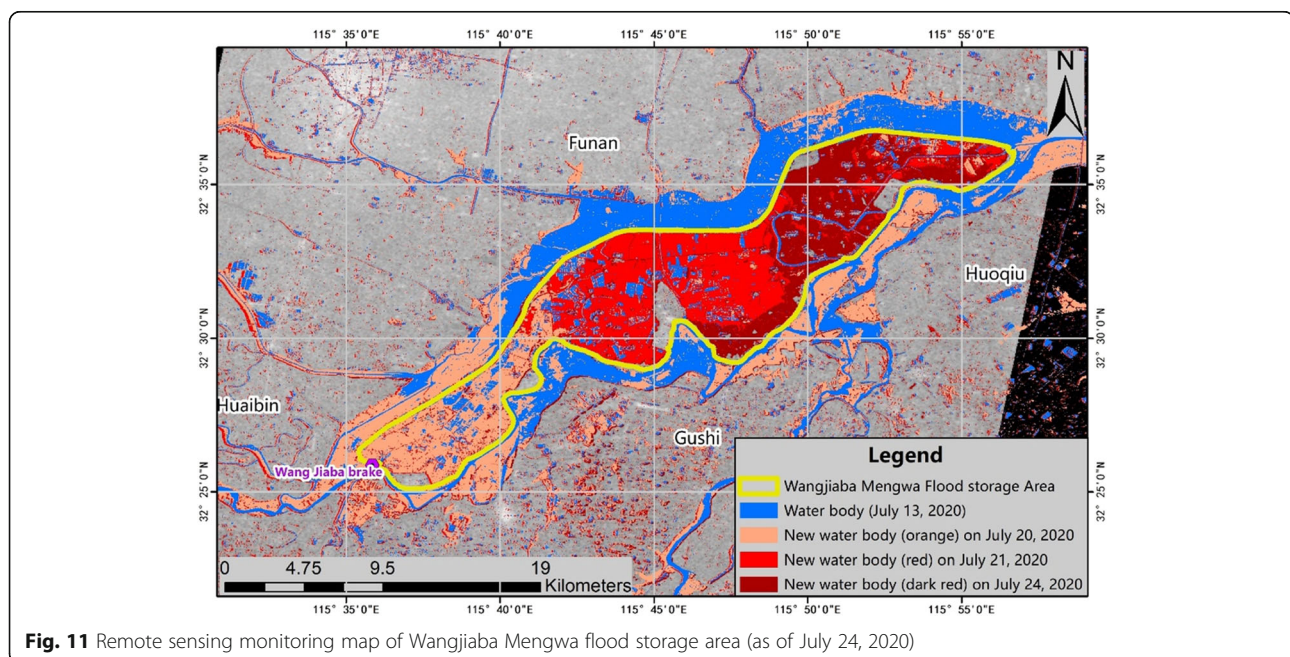




Fig. 12 The distribution of sentiment tendencies of the flood disaster public opinion in Weibo (July 20–24, 2020)

planning and infrastructure construction of physical cities, and implementing corresponding policies, can the construction of smart cities be truly implemented.

Code availability

Not applicable.

Authors' contributions

The author(s) read and approved the final manuscript.

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Availability of data and materials

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Competing interests

The author declares that they no competing interests.

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References

- Enders, M. R., & Hoßbach, N. (2019). *Dimensions of digital twin applications—a literature review*. 25th Americas Conference on Information Systems, AMCIS 2019.
- Jimenez, J. I., Jahankhani, H., & Kendzierskyj, S. (2020). *Health care in the cyberspace: medical cyber-physical system and digital twin challenges*.
- Kaur, M. J., Mishra, V. P., & Maheshwari, P. (2020). The convergence of digital twin, IoT, and machine learning: transforming data into action. In *Digital twin technologies and smart cities*.
- Kharchenko, V., Illiashenko, O., Morozova, O., et al. (2020). Combination of digital twin and artificial intelligence in manufacturing using industrial IoT. In *2020*

IEEE 11th international conference on dependable systems, services and technologies (DESSERT). IEEE.

- Khatib, M. M. E., Al-Nakeeb, A., & Ahmed, G. (2019). Integration of cloud computing with artificial intelligence and its impact on telecom sector—A case study. *iBusiness*, *11*(1), 1–10.
- Kritzinger, W., Karner, M., Traar, G., Henjes, J., & Sihn, W. (2018). Digital twin in manufacturing: a categorical literature review and classification. *IFAC-PapersOnLine*, *51*(11), 1016–1022.
- Li, D., Shao, Z., Yu, W., Zhu, X., & Zhou, S. (2020). Public epidemic prevention and control services based on big data of space-time location make cities smarter. *Journal of Wuhan University Information Science Edition*, *45*(4), 475–487, 556. <https://doi.org/10.13203/j.hugis20200145>.
- Li, R., Zhao, Z., Zhou, X., et al. (2017). Intelligent 5G: when cellular networks meet artificial intelligence. *IEEE Wireless Communications*, *PP*(5), 2–10.
- Liu, S., Bao, J., Lu, Y., et al. (2020). Digital twin modeling method based on biomimicry for machining aerospace components. *Journal of Manufacturing Systems*.
- Mondoro, A., & Grisso, B. (2019). On the integration of SHM and digital twin for the fatigue assessment of naval surface ships. In *Structural health monitoring 2019*.
- O'Dwyer, E., Pan, I., Charlesworth, R., et al. (2020). Integration of an energy management tool and digital twin for coordination and control of multi-vector smart energy systems. *Sustainable Cities and Society*.
- Talkhestani, B. A., Jazdi, N., Schögl, W., et al. (2018). Consistency check to synchronize the digital twin of manufacturing automation based on anchor points. *Procedia CIRP*, *72*, 159–164.
- Tao, F., Cheng, J., Qi, Q., et al. (2018). Digital twin-driven product design, manufacturing and service with big data. *The International Journal of Advanced Manufacturing Technology*.
- Tao, F., Ma, X., Hu, T., et al. (2019). Research on digital twin standard system. *Computer Integrated Manufacturing Systems*, *25*(10), 2405–2418 (in Chinese).
- Tao, F., & Qi, Q. (2019). Make more digital twins. *Nature*, *573*, 490–491. <https://doi.org/10.1038/d41586-019-02849-1>.
- Tao, F., Zhang, H., Qi, Q., et al. (2020). Digital twin ten question: analysis and thinking. *Computer Integrated Manufacturing Systems*, *026*(001), 1–17.
- Yan, J., Zlatanova, S., Aleksandrov, M., et al. (2019). Integration of 3D objects and terrain for 3D modelling supporting the digital twin. In *14th 3D Geoinfo conference*.
- Yu, Y., Fan, S., Peng, G., et al. (2017). Application of digital twin model in product configuration management. *Aviation Manufacturing Technology*, *60*(7), 41–45.
- Zheng, Y., Yang, S., & Cheng, H. (2019). An application framework of digital twin and its case study. *Journal of Ambient Intelligence and Humanized Computing*, *10*(3), 1141–1153.

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