Research on the Construction of Highway Traffic Digital Twin System Based on 3D GIS Technology

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Abstract. Under the background of smart city construction, modern information technology has been continuously innovated and developed, which has effectively promoted the development of highway transportation in China, and GIS technology has effectively promoted the development speed of highway transportation informationization in China. As an important geographic information system, GIS technology has obvious technical advantages in traffic information data collection, information data analysis and processing, and promotes the road traffic to develop towards informationization gradually. In order to accelerate the mature development of road transportation, with the support of GIS technology, the road transportation digital twin system is gradually constructed. As a revolutionary technology in the development of highway transportation, digital technology promotes the development of highway transportation in a green, open, and shared direction, laying a solid foundation for the quality of highway engineering construction. Based on this, this article analyzes the overview of GIS technology, explores the digital twin technology, and specifically discusses the modeling process of the road traffic digital twin system, in order to verify the feasibility of the practical application of the road traffic digital twin system.

1. Introduction

Digital twinning itself has multi-disciplinary attributes, and with the support of GIS technology, it promotes the interaction between virtual and reality. In order to better construct the digital twin system of highway transportation, the related researchers aim to build the transportation information model +GIS model, further promote the integration of virtual model and information data, and ensure the feasibility of digital twin technology application in the field of highway transportation. The state regards highway transportation system as an important guarantee of the four modernizations, actively constructs the intelligent transportation mode in internet plus, and ensures the construction of two-dimensional electronic maps through the construction of three-dimensional models, so as to achieve the information management goal in the transportation operation period. Therefore, in the operational life cycle of highway traffic engineering design, construction, etc., based on the smooth highway traffic operation mode, the 3D GIS scene should be constructed, and the functional analysis of modeling, data collaboration and visualization should be strengthened. So as to better break through the limitations of technology application and promote the application practice of intelligent transportation system.
2. Overview of GIS technology

GIS technology, an information system integrating geographic information and geographic attributes, has obvious functional advantages in information data collection, management and storage. GIS system, as the infrastructure of highway traffic information construction, realizes data division by combining electronic maps, satellite navigation and other equipment, and provides users with more convenient functions such as data query and target management. With the continuous development of modern information technology, GIS technology plays a huge role in the development of highway traffic construction. Especially in the links of highway traffic planning and design, engineering construction, etc., GIS technology provides reliable technical support and data support to improve the quality of highway engineering, and promotes the efficient operation and development of highway traffic. In the information age, GIS technology promotes the development of highway traffic informatization. Using GIS technology to build a three-dimensional spatial model and obtain terrain data information in real time, the informationization and visualization development of engineering planning and design have been realized, the data processing ability has been greatly improved, and the planning and site selection have been improved scientifically, providing data and technical support for highway traffic planning and design. Relevant highway traffic engineering departments use GIS technology to carry out survey and route design, which improves the quality of highway engineering construction in an all-round way. With the support of 3S technology, they build an information database, strengthen the storage of highway traffic information, provide theoretical results for the follow-up traffic operation planning, actively carry out intelligent traffic strategic development routes, and effectively convert a large amount of stored engineering information into highway survey results. In addition, with the application of GIS technology, it can effectively simulate, compare and quantitatively analyze the highway traffic planning and design schemes, and realize the overall control of highway engineering quality.

In order to build an intelligent transportation system, GIS technology, Internet technology, computing technology, etc., are applied to the construction of intelligent transportation system, continuously optimize the transportation system, provide high-quality transportation services, and promote the development of green transportation industry. In the context of smart city construction, it is particularly important to strengthen the improvement and supplement of geographic information to ensure that the development of highway transportation informatization through GIS technology is used to create a new situation in transportation.

3. Analysis of digital twin Technology

3.1. Definition of digital twin Technology

Digital twinning is to build a mirrored digital world for the real physical world, copy a physical object in a digital way, simulate the behavior of objects in the real environment, and apply it to the construction of highway traffic system, which can realize the management of the whole life cycle of highway traffic operation. Digital twin itself is a concept of the Internet of things. It is a virtual mapping of the real world through modeling, providing data support for relevant personnel to evaluate the physical world. Driven by the development of technology, all sectors of society attach great importance to the application of digital twin technology to ensure a mapping in the physical world. Digital twinning technology has been introduced into China for a short time, and it faces certain difficulties in practical application. For example, in simulation modeling, the accuracy of modeling is required, and multi-physical scene modeling and high fidelity simulation are the most important technical problems to be solved at present. To put it simply, digital twinning is a process of simulating multiple physical quantities, scales and probabilities by making full use of physical models, updating sensors and running historical data, and reflecting all information in the whole life cycle of physical equipment. At present, the digital twin technology is widely used in the fields of industrial manufacturing, smart city construction, etc., and the difficult tasks in the real world are constructed in the virtual world by means of modeling, which is constantly tried and expanded, so as to find a quick solution to the problems in real life [2]. The model construction of highway traffic digital twin system based on 3D GIS technology can better support the
practical solution of highway traffic carrying capacity, simplify the process and solve the problem of high operation difficulty. With the support of digital twinning technology, various attempts have been made to accurately design the traffic operation lines and optimize the specific design, so as to ensure that the optimal solution of highway traffic can be simulated through repeated tests of the simulator, and then all the information data obtained from 3D modeling can be brought into real life, thus fully ensuring the rationality and scientificity of intelligent traffic scheme design, and highlighting the status of intelligent hub in digital twinning technology cities.

Digital twinning is an important application system for smart city construction. Based on the integration of multi-category technologies and GIS+ digital twinning technology, new functional application modules such as surveying and mapping, logo perception, 3D modeling and simulation are added, which comprehensively improves the feasibility of building digital twinning platform system for highway traffic. In the construction of 3D model, it can better integrate the information model platform, give full play to the information collection function of digital twin technology, and ensure the synchronous operation of virtual world and real world in the process of 3D data generation.

3.2. Characteristics of digital twin Technology
At present, some countries regard digital twinning as a great opportunity to change the development of the industry, in order to understand the actual operation mode of the physical world more transparently through the ability of big data analysis and processing. Some enterprises regard digital twinning as a key link in the manufacturing of "smart interconnected products", and ensure that the real world is optimized and fed back during the model building process [3]. This paper mainly explores the model construction based on 3D GIS technology, so as to ensure that the digital twin technology, supported by cutting-edge technologies such as Internet technology, big data technology and artificial intelligence technology, can better improve the rationality of the construction of highway traffic digital twin system, and then build a system engineering based on reality. With the support of various information technologies, the application prospect of digital twin technology is very broad. In the future, digital twin technology will create a steady stream of application value in various industries.

3.3. Key technologies of digital twin
Relevant researchers believe that in the construction of 3D GIS scene, the highway transportation infrastructure can be fully mapped in the 3D world in the form of digitalization, which can better break through the limitations of 2D system. Some researchers believe that the construction of digital twin system of highway traffic needs to strengthen the model construction of the whole life cycle of the project in the modeling process, and better divide the corresponding twin data accurately in the virtual scene [4]. Based on the rapid development of digital twinning technology, most institutions and enterprises strengthen the application research and practice of digital twinning technology, and conduct comprehensive research on digital twinning technology. The functional modules of digital twin system include acquisition transport layer, modeling layer, function realization layer, human-computer interaction layer, etc. Each layer is an extension and expansion of the previous functional layer. Key technical advantages are as follows:

3.3.1. Multi domain scale modelling. Multi-domain modeling of digital twins is a process of merging physical systems. However, it is difficult to make deep multi-domain integration, and it is difficult to break through the technology. Multi-scale modeling is to improve the modeling accuracy by connecting the physical states of different time scales. Based on this, improving the accuracy of multi-domain scale modeling with digital twin technology can effectively solve the bottleneck problem of virtual world construction.

3.3.2. Data acquisition and transmission technology. The function of the digital twin system is based on the data acquisition layer and the data transmission layer, which requires the system sensors to follow the advantages of rapidity and high precision in practical application. Based on this, relevant researchers
strengthen the improvement of sensor accuracy, and it is the primary problem to build sensor networks compatible with physical systems. At the same time, the transmission of data sensors requires higher speed of data transmission network, which ensures the safety of data transmission. In addition, the digital twin system itself has the function of analyzing and processing massive information data. From the perspective that historical data need to be stored by sensors, it is particularly important to optimize the distribution architecture, storage mode and retrieval mode of the digital twin system and extract effective information data from massive information [5]. Therefore, through the analysis of digital twin system technology, this paper applies it to the construction of highway traffic digital twin system to ensure the establishment of a three-dimensional geometric model of GIS+ digital twin technology.

4. Modeling process of highway traffic digital twin system

4.1. Modeling scheme

Relevant highway traffic surveyors found in the field survey that the traffic is mainly linear engineering, and there are some limitations in simply using BIM technology, and the model monomer processing technology is not perfect. Based on the characteristics of highway traffic operation, three-dimensional models with different life cycles can be constructed by combining digital twin technology. Digital twinning system can provide a new way of surveying and mapping in the transportation industry, and transform road horizontal and vertical design into computer aided design. With the support of digital twinning technology, relevant researchers can better map the GIS vector elements in the electronic map, ensure to improve the simulation effect of the physical world, and better map the traffic structures to the digital earth by constructing the highway traffic twinning system. In the whole modeling process, it is necessary to strengthen the collection and processing of geometric information data and realize the organization and management of virtual model data [6]. In the highway traffic operation system, it is necessary to use 3S technology to extract information, which provides convenient conditions for obtaining modeling data. Generally, the data information obtained by RS technology can be used as the data source of highway traffic monitoring during operation period. To realize the digital twin technology, it is necessary to strengthen the connection between the virtual world and the physical world by establishing the three-dimensional geometric model. With the support of the model construction scheme, the scientific planning of highway traffic lines can be effectively realized. By inputting various data parameters in reality into the virtual model, the foundation for orderly operation of the road traffic system can be better laid.

4.2. Three-dimensional model building process

3D model building process (as shown in Figure 1):

![Figure 1. Three-dimensional geometric model diagram](image)

Ground topographic survey Satellite elevation the road is horizontal and vertical Texture material Scene Digital Elevation Model (DEM) Three-dimensional traffic abstract model Reference terrain DEM Three-dimensional traffic abstract model
Independent CGA modeling Assembly CGA modeling
Two-dimensional map virtual model Three-dimensional map virtual model
TIF, txt point file Auxiliary correction Secondary design output point file (txt) GIS data management tools Rule code Rule code Polyhedral COB Map and scene output Modeling data processing Modeling terrain and abstract model generation Modeling Virtual model output

In the specific modeling process, relevant personnel need to improve the modeling data processing ability and extract effective information data from GIS system, including topographic survey data, satellite elevation data, road horizontal and vertical information sources, photos of cement and asphalt pavement, etc. The information of satellite elevation data mainly comes from the extraction of ground topographic survey information, and the accuracy of data extraction is improved by scanning. In the stage of highway design, in order to do a good job in the early stage of traffic road route selection, it is necessary to investigate the engineering site. Among them, the survey accuracy of topographic and ground object drawing data is high. With the support of GIS geographic information technology+digital twin technology, the digital processing of CAD drawings can be better realized, thus improving the lofting accuracy in actual road planning and ensuring the consistency between drawing design and actual route planning and design. In order to improve the continuous measurement of traffic section topography in the actual planning of highway traffic, it is necessary to strengthen the control of sampling point accuracy. In fact, in the description of geographical area, it is necessary to correspond each pixel to the corresponding area to ensure the accuracy of terrain elevation description [7].

In order to ensure the feasibility of virtual modeling, it is necessary to take abstract model as an important modeling basis, and ensure that the horizontal and vertical information of traffic lines is displayed in three-dimensional space. Based on this, in the establishment of 3D abstract model, drawing software can be used to restore all elements of horizontal curve into route objects, and the route object matching design can be carried out according to the profile elements in the design documents, thus improving the rationality of profile design and accurately correcting the modeling reference terrain in real time. At the same time, GIS technology can be used to export the generated data information, continuously carry out topographic survey, better obtain the generating line elements collected in GIS system, and ensure that the abstract modeling design accurately provides the location information of lofting points.

In the process of rule modeling, it is required that highway traffic route planning should reflect the outline to the greatest extent and reflect the data information at the digital twin level. Especially in the period of highway traffic operation, it is necessary to build the model of pile foundation and other components, which reflects the rationality of geometric size design, fundamentally improves the accuracy of twin data acquisition, and better meets the data information required by rule modeling. During the modeling and design, the ultimate goal is to transform the horizontal and vertical information of the road centerline, the original topographic map and the cross-sectional design drawing into a three-dimensional geometric model. By using the geometric principle of CGA language, the model can be established quickly. The modeling effect of CGA (as shown in Figure 2), the relevant personnel judge the elevation difference of the line by CGA "integrand" principle, fully consider the error range, and finally realize the interchange modeling of highway traffic line by modeling and verifying the generated code with the actual terrain and road. At the same time, the digital twin data in abstract modeling is taken as the relevant parameters of road width design, and then the goal of dynamic modeling is achieved. In the whole modeling process, the twin data comes from the static structure attribute data, and the information data and application data collected by the system are monitored throughout the whole process, and the professional vector diagram is automatically generated, thus providing a basis for the construction of the virtual model. In the process of virtual model construction, the twin monitoring machine code is used to connect with the model, and vector intersection and frame selection are realized on the basis of professional vector layer construction, and then spatial query is completed. Through the platform of digital twin system, the practical engineering demonstration and information engineering query are carried out, and the content of model construction is clearly understood with the support of 3D visual interface.
4.3. Establishment of virtual model
The construction of highway traffic digital twin system based on 3D GIS technology needs to build a virtual model on the basis of traffic facilities classification tree, and fully consider the storage and interaction modes of twin data. With the establishment of the virtual model, the virtual world is basically formed. Taking the bridge deck section of a highway engineering as an example, the information data of concrete frost resistance grade and dynamic traffic volume information are included in the modeling, and the information can be effectively stored by establishing a three-dimensional model database. In order to better solve the transmission effect of information in the model, symbol entities can be distinguished by means of identification analysis, which can be marked as type area, pile number area, highway number area and component number area. In the type area, the ontological relationship of each transportation infrastructure component is clearly presented, so as to realize the coding identification of each path, better represent the whole highway engineering planning situation, effectively avoid the confusion of pile number coding information and mileage location information, and reduce query errors. In the chainage area, each road section can be accurately located, and GIS technology can be used to design and plan, so as to improve the collection of data information of sampling points, and realize the dynamic tracking of highway traffic information under the establishment of the model. In order to ensure the uniqueness of highway numbering, it is necessary to ensure the uniqueness of machine coding in the design of component numbering. In the construction of virtual model, the real highway traffic construction, abstract model and rule model are corresponded, and the virtual model is filled with machine code by writing program, so as to realize the validity of filling each pile number code.

4.4. Analysis of digital twin data
Twin data includes physical entity data, service data, knowledge data and fusion derived data. In the road traffic twinning system, the twinning data mainly shows that PE data is taken as the basis of digital twinning drive, and analyzed according to physical entities (including real-time operation state and performance of road traffic, etc.), ensuring that the static attribute data such as design performance are referenced, and the physical entity elements are fully reflected. Among them, VE data contains multi-dimensional and multi-scale data information, and depicts PE data model, thus increasing the relevance of VE data. For the service data in the twin data, it includes algorithms, model building, data processing methods and so on. When studying the relationship between virtual model and twinning data, this paper completes data twinning by matching the machine code of virtual model, and obtains the corresponding data information better by constructing the machine code of virtual model. In the application of GIS technology, the abstract vector is generated according to the 3D entity model, and the entity world is better mapped in the virtual model. Based on GIS, the virtual entity data is generated by vector analysis of spatial analysis tools. Physical entity itself has geographical information characteristics, which can effectively store information on the premise of satisfying all elements of GIS system, and realize GIS vector interaction according to professional vector maps such as highway traffic planning route and wind speed, and improve the relevance of model establishment. At the same time, in the process of drawing professional vector layers, relevant designers can better plan storage space and information, strengthen the maintenance of data information, and basically realize the analysis of visualization.
In order to accurately represent the twin data collection points, it can be assumed that the distance collected to the plane is \( x \), and the corresponding point projected to the plane is \( x_0 \). Set \( w \) as a vector in the vertical plane and \( y \) as the distance to \( x \), then the set distance can be expressed as:

\[ x = x^0 + \gamma \frac{\omega}{\|\omega\|}, \]

where \( \|\omega\| \) is expressed as the norm. When \( x_0 \) satisfies \( f(x_0) = 0 \), it can be substituted into the equation \( w^T x + b = 0 \), and finally \( \gamma = \frac{\omega^T x + b}{\|\omega\|} = \frac{f(x)}{\|\omega\|} \) can be obtained. The calculation can accurately reflect the actual geometric relationship, and provide a basis for the twin data analysis in the data in the modeling.

5. Data fusion and system verification

In the actual establishment of highway traffic digital twin system, the twin data is constructed based on different levels. In the physical entity model construction, the physical model, behavior model and rule model are specifically divided. In the process of constructing geometric data model, the twin data can be calculated by using data fusion algorithm, so as to obtain the twin data. On the basis of physical entity data, physical models in geometric models enhance PE physical attributes, strengthen the judgment of twin data attribute information, enhance the prediction ability of virtual entity models, better evaluate virtual entity data and strengthen the control of virtual entity data models. In the process of constructing geometric model, it is necessary to comprehensively consider the twin data of highway bridge deck and other road sections, and focus on the data layer algorithm to strengthen the consistency between display and virtual data. In order to improve the mapping effect of the virtual model, the relevant modelers can position according to the advantages of GIS technology, RS technology and floating car technology, strengthen the control of errors, avoid positioning errors caused by directional transportation in GIS, and then dynamically track vehicle traffic signals.

As far as the data information that is difficult to obtain in highway traffic planning and design is concerned, estimation and measurement are the factors that affect the modeling of virtual entities. Based on this, the relevant modelers can accurately find the change rule of data information based on the data algorithm, and take the virtual geometric model vehicle networking as a breakthrough point to better solve the problem of vehicle positioning and modeling signal transmission speed. At the same time, with the support of the digital twin system of highway traffic, the calculation of vehicle location points can be realized, and the potential safety hazards of vehicle driving at night can be judged and evaluated, and then effective emergency control measures can be formulated, and the boundary between virtual model and physical entity can be clearly defined, so as to ensure that the vehicle runs in normal track and fundamentally optimize the bottleneck problem that is difficult to solve in the real world. According to the data information provided by sensors, professional vector layers should be measured, and the relationship between professional vector layers and virtual models should be fully considered, so as to realize the perception and monitoring of transportation system, optimize traffic routes in time, control road traffic congestion, strengthen the prediction of road traffic accidents and ensure the boundary control of traffic flow areas.

At the same time, the representation layer information reflects the authenticity of the physical space based on the twin data fusion of the data layer, and provides better support for the Highway Bureau and the Transportation Bureau to control the road traffic operation. Based on geometric models, twin data and algorithms involved in physical features. In the process of establishing virtual model and simulation model, it is necessary to strengthen the verification of highway traffic digital twin system, and strengthen the verification of the whole life cycle and framework of the system.
6. Conclusions
To sum up, the construction of highway traffic digital twin system based on 3D GIS technology has certain limitations. Relevant researchers need to further strengthen the feasibility analysis of the application of digital twin technology to ensure the development of highway transportation.

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