International Journal of Frontiers in Engineering Technology
ISSN 2706-655X Vol.4, Issue 5: 25-32, DOI: 10.25236/IJFET.2022.040506

Development of 3D Simulation Platform of Urban Traffic Based on Cesium

Hongqing Feng*

North China University of Technology, Beijing, China
f18236901857@163.com
**Corresponding author*

Abstract: *In order to meet the increasing aesthetic needs of the public, improve the integration of traffic planning and urban planning, facilitate traffic simulation data analysis and effect display, and facilitate traffic planning scheme evaluation, this paper is based on cesium to develop a three-dimensional simulation platform for urban traffic, design Celestia came out, and based on common simulation software such as sumo, Paramics, Vissim, and used Python and JavaScript language to design and develop a web page simulation platform to display the 3D effect of road traffic simulation for users, and added a lot to improve the simulation effect, which is convenient for users. Functions to evaluate simulation effects. Users only need to open the website, upload the simulation file or select the map area in the map link box, select the simulation parameter requirements, and wait for the data to be read in the background to get an interactive 3D traffic simulation. This work with convenient operation, powerful function and broad development space largely fills the blank of domestic road traffic 3D simulation. Experiments show that when the number of divisions reaches 15, the resolution is 0.037m (within 5 cm), which can meet most practical needs.*

Keywords: *Cesium, Urban Transportation, 3D Development, Simulation Platform*

1. Introduction

Traffic simulation, this process is essential before urban planning and road planning, but currently domestic traffic simulation is still in the 2D stage, and only a few traffic simulation software adds simple 3D effects. The information presented by the plane traffic simulation is limited, which is insufficient for the three-dimensional display of the road traffic model, cannot directly reflect the road conditions, and the simulation effect is difficult to meet the aesthetic needs of users. Therefore, the simulation technology and virtual reality technology are combined to make the simulation process and results. 3D visualization is an inevitable trend. At the same time, most traffic simulation software is too limited to the traffic field, and the integration with other fields is quite limited. For example, most simulation software simulation content is limited to road network, signal lights, traffic flow, etc., and can only complete the work of traffic planning, but cannot intuitively feel the effect of urban planning. In many cases, traffic planning and urban planning are inseparable [1, 2].

There are many practical and theoretical research results on urban transportation design. For example, Maria Diez J et al. combined the concept of smart city to create GIS to manage water data, and finally visualized by Google Earth [3]. Based on GIS, Anelkovi S designed a waterway comprehensive supervision system combined with ArcGIS Engine and VS2008, which loaded and displayed waterway data, improving the supervision efficiency [4]. It can be seen that the simulation of urban traffic and the three-dimensional research are the top priorities, and the combination of the two is also an inevitable trend.

The main purpose of this paper is to research the development of the 3D simulation platform for urban traffic based on cesium. In this paper, a multi-scale representation method of 3D route scene based on dynamic segmentation is proposed, which realizes the data organization and dynamic expression of 3D route scene. A multi-scale spatial data organization method for 3D line scene is designed. Combined with the scaling up algorithm, a linear reference data organization method for multi-scale expression is proposed, which realizes the spatialization of non-spatial data of multi-source heterogeneous data in 3D line scenes, which is conducive to the efficient organization and management of data, and is the best way to organize and manage data in 3D line scenes. Dynamic expression provides support. An event-driven linear scene dynamic expression method is designed. With the support of multi-level events and version management, it can effectively solve the problems of different time granularities in the process.

2. Design and research on the Development of 3D Simulation Platform for Urban Traffic Based Cesium

2.1. *Features of Cesium*

Cesium is a new virtual earth technology, which is developing rapidly. It has the advantages of Web GL, and also has the following characteristics [5, 6]:

2.1.1. *Multi-view Features*

Cesium can provide three view modes, as shown in Figure, which are 3D view, 2D view and 2.5D view. In the 3D view, the 3D scene is displayed by perspective projection, and the object is defined as Scene Mode.Scene3D; in the 2D view, the 2D map is displayed by the orthogonal projection, and the object is defined as Scene Mode.Scene2D; In the 2.5-dimensional view (Columbus view), the map is displayed by perspective projection, and the object is defined as Scene Mode. COLUMBUS_View.

2.1.2. *Multi-map Projection Features*

Cesium supports two projection types: map projection and Web Mercator projection. Web Mercator projection is the map projection method used by most map services, such as Google Map, Microsoft's Bing Map and Arc GIS Online, so Cesium can load the above map image service data resources.

2.1.3. *Various Image Data Service Features*

Cesium internally repackages map data from ArcGIS services, Google Map services, Bing Map, and Open Street Map, among others. At the same time, map services with OGC specifications are also supported.

2.1.4. *Features of Various Types of Spatial Elements and Vector Data Sources*

Cesium supports various types of spatial elements, such as basic points, lines, surfaces, complex elevations, ellipsoids, cylinders, walls, etc. can be visualized. At the same time, for the material effects of the added space elements, users can define their material types according to their own needs. Cesium also supports loading and displaying vector data sources such as KML.

2.1.5. *Load 4D Data Features*

Cesium can load and display 4D data, that is, data containing time information, and can perform visual simulation of scenes containing time data. CZML is a data format, which is a subset of the JSON data format. It was proposed by Cesium and defines the characteristics of spatial elements that change over time, including changes in points, lines, surfaces, and 3D models. Through the Czml Data Source class Instantiate it to complete the visualization of CZML data. The Timeline timeline control in Cesium can implement functions such as fast forward, fast rewind, and pause in the scene simulation [7, 8].

2.1.6. *Characteristics of Terrain Data on a Global Scale*

Cesium can not only visualize terrain data based on height map, but also visualize terrain data based on STK high precision. It supports worldwide STK-based high-precision terrain data services, which can display realistic effects such as water flow

2.1.7. *Cesium Features*

(1) It is open source, written in the JavaScript programming language, and integrates some JavaScript frameworks commonly used in the front end;

(2) No need to install plug-ins, only a browser that can provide WebGL technology, and can run in different operating systems;

(3) Support a variety of visualization scenarios, and can switch smoothly;

(4) The AJAX function is repackaged to realize asynchronous requests for large-scale and massive spatial data.

(5) Compatible with the WMS, WFS and other network service specifications formulated by OGC,

and the map data is loaded by the remote service and visualized on the web page [7, 8].

2.2. *Principles of Designing 3D Line Scene Data*

3D route scene relational database design The 3D route scene relational database mainly uses non-3D symbol data to build a multi-source heterogeneous data management system, including terrain and image databases, attribute information data, and operation and maintenance databases [9, 10]. The following principles should be followed in data organization and management design:

(1) The storage structure of relational data is determined according to the data type and data format, and is not static.

(2) The same type of data in different states can be divided into different levels according to the data level, and an association relationship can be established in the database.

(3) Taking into account the two levels of data management and data application, with practicality and ease of use as the main principles.

2.3. *Problems Existing in Cesium 3D Model Generation*

The 3D model can truly reflect the buildings and surrounding environment in the shooting scene, providing higher accuracy and authenticity. For the oblique photography 3D model loaded based on Cesium, there are the following problems [11, 12]:

(1) The oblique photographic images of UAV aerial photography do not meet the modeling requirements of modeling software. Restricted by factors such as weather, equipment, shooting technology, etc., the quality of photos may be unclear, chromatic aberration, occlusion, etc., and the overlap of photos may not meet the requirements. For photo areas that fail to meet the requirements, aerial photography or partial supplementary photography will be taken.

(2) For the model data generated by 3D modeling software, its format cannot be directly loaded and visualized by Cesium. Although the glTF format data generated by Smart3D can be supported, the 3DTiles data specification was launched in Cesium, which makes the data generated by Smart3D still unable to be perfectly supported, and further 3D model data format conversion is required.

2.4. *Algorithm Research on the Development of Cesium-based Urban Traffic 3D Simulation Platform*

2.4.1. *Vehicle Generation Model*

In micro-traffic simulation, the vehicle generation model is the most basic model, and its purpose is to solve the input problem of traffic simulation. The input of traffic flow in the traffic system belongs to discrete events, the generation of vehicles has no certain rules, and the occurrence of various traffic situations is discrete and random in time and space. The parameters included in the vehicle generation include the time when the vehicle is generated, the initial position of the vehicle, the speed of the vehicle, and the like. Assuming that the arrival time of the vehicle follows a Poisson distribution, the headway follows a negative exponential distribution. The vehicle generation model is as follows:

$$\begin{aligned} t_{i+1} &= t_i - \ln(r_i)/\lambda, \lambda > 0, 0 < r_n < 1 \\ r_i &= ((ax_i + c)\operatorname{mod}(m))/m \end{aligned} \tag{1}$$

In the formula: ti and ti+1 refer to the time when the i-th vehicle and the i+1-th vehicle enter the road network; λ is the vehicle arrival rate of a certain OD; ri is a random number obeying a uniform distribution in the interval [0, 1]. a=8K+3 and close to or equal to a=2P/2, K is an arbitrary integer, P is a machine constant; m=2j, where j is an integer, and m/4 is greater than the required random number sequence length; ri needs a seed x0 is used as the starting point of the recursive operation, and x0 is an odd number less than m.

2.4.2. *Vehicle Following Model*

The system adopts the safety distance model based on the braking process. When the driving situation of the vehicle in front changes, the driver behind analyzes and judges the obtained information. If the critical value of the safety distance is reached, the vehicle behind will decelerate and brake, and even the final vehicle speed will be reduced to zero. Assume a typical state: the vehicle ahead stops suddenly in place. Then the safe distance model looks like this:

$$S_c = v_0 t_d + \frac{v_0^2}{2a_m} + L \tag{2}$$

Among them, Sc represents the safety distance between the adjacent vehicle in front and the rear vehicle; v0 represents the speed of the rear vehicle before braking; td represents the braking delay time, which is the sum of the driver's reaction time and the brake coordination time, generally 1.2~2s; am represents the maximum deceleration of the rear vehicle, which is related to the vehicle's own dynamic characteristics, generally taking 6~8m/s2; L represents the safe distance between the front vehicle and the rear vehicle after the vehicle stops.

3. Experimental Research on the Development of 3D Simulation Platform for Urban Traffic Based on Cesium

3.1. 3D Model Establishment

Smart3D is a software system for automatic 3D modeling of image data. The object to be modeled is static. Combined with the camera shooting properties, the position and parameters of the captured image data, and the information related to lighting control, it performs aerial triangulation operations on it to complete the model reconstruction. Output corresponding geographic information for later browsing and processing. The output formats of Smart3D 3D modeling are OSGB, OBJ, S3C, 3MX, dae, etc. Using Smart3D to build a 3D model, the steps are as follows:

3.1.1. Image Acquisition and Data Inspection

Before the drone shoots, the configured camera lens is verified to obtain the camera's internal orientation elements and the poor distortion of the objective lens. After the shooting is completed and the image data is obtained, each image is checked to determine whether there are unqualified phenomena such as missed shots and data loss, and make up or retake the unqualified shooting areas.

3.1.2. Null Operation

The original image is preprocessed first, including leveling, adjusting color, brightness and contrast. The ground control points in the image are identified by Smart3D software, and the empty three operation is performed. During the operation, the same name is obtained according to the feature point extraction and matching algorithm, and then the coordinates of the external orientation element and the connection point of each image are determined.

3.1.3. Rebuild Generation

After three-dimensional encryption, the 3D TIN mesh is constructed to generate a white body 3D model, and texture mapping is performed on the model to construct a real 3D model. It supports the reconstruction of a single object, and supports editing or re-generation of models that are not satisfied with the construction effect, thereby improving the optimization ability of 3D model data.

3.1.4. Texture Mapping

Texture mapping is performed on the model to construct a 3D model of the real scene, and the position information of the object is matched with the texture information. A true 3D model can be generated after multiple texture mapping optimizations.

3.1.5. Export the Model.

Smart3D can generate 3D model data in OSGB, OBJ, Max and other formats. For the data generated by oblique photography, an S3C index file can be established, and the model can be loaded and displayed in the same reference system by calling the index file, and finally the entire 3D scene can be seen. For post data format conversion processing, visualize on Cesium platform.

3.2. Functional Requirements

Since Cesium-based spatial information visualization is based on B/S architecture, it is necessary to build both the server side and the browser side:

3.2.1. Server Side

Store data and load it asynchronously to improve the fluency of visualizations. The visualization data in this study are placed on the server, the data is retrieved through the HTTP protocol, and Node.js is used as the server to realize the release of the service.

3.2.2. Web Front End

(1) Browsing requirements: Visualized information is displayed in the form of a virtual globe, and users can browse through multiple views, multiple scales, and multiple perspectives in the visualization scene.

(2) Layer requirements: Manage layers, add and delete layers according to user needs, including terrain, images, 3D models and other layers for users to choose.

(3) Trajectory simulation requirements: According to user requirements, input the corresponding trajectory and simulate it on the Cesium 3D earth.

3.3. Construction of 3D Line Scene Symbols

The construction of 3D line scene symbols mainly includes geometric construction and texture mapping:

(1) Geometric construction. According to the collected raw data, the three-view size and unit of the model are determined, and then the point, line and surface of the symbol geometric model of the three-dimensional line scene are determined. The 3D line scene symbol is different from the 3D solid model. It realizes the features of simplicity and ease of use on the basis of ensuring the feature information of the solid model.

(2) Texture mapping. It mainly fills the original geometric model with texture to make it more realistic and closer to the three-dimensional entity in the real scene. First of all, professionals will collect on-site textures, and the collected texture graphics will be assembled into a complete 3D line scene symbol texture image.

1) For the linear model, the head and tail links are carried out in the vertical direction, while ensuring the integrity and smoothness of the link parts. The surface area ofthe linear model is determined by actual measurement, the matching position of the texture image is determined according to the boundary coordinates of the filling range, a one-to-one mapping relationship between the image and the linear model is established, and finally the pixel valuesare filled into the space represented by the linear model.

2) The texture filling method of the planar model is actually an extension of the linear texture filling. It performs continuous mapping in the two-dimensional coordinate direction, and at the same time, there can be no discontinuous state during the filling process. Determine the range of the area that needs to be filled by the texture according to the actual object, and then divide the area into a grid according to the texture image unit, and fill the grid unit and the texture image unit face-to-face, and finally realize the entire coverage texture filling.

3) The texture filling of the body model can be regarded as the texture serialization filling of multiple surface models and linear models. It is important to pay attention to the connection relationship between the textures of each surface of the body model, so as to ensure that each surface and line are kept correct sequence relationship.

4) Point-like models are relatively easy, and their texture objects are fixedly filled.

4. Experimental Analysis of the Development of 3D Simulation Platform for Urban Traffic Based on Cesium

4.1. Conversion of One-dimensional Linear Coordinates

The construction of linear reference and 3D scene provides the location basis for the import and splicing of primitive models, and also lays the foundation for adding attribute data. The mileage is converted into latitude and longitude coordinates through mileage correction, and the mileage position information in the route data is converted into coordinates under the geographic coordinate system, realizing the conversion from one-dimensional linear coordinates to geographic coordinates. The relevant data conversions are shown in Table 1 below:

Table 1: Coordinate Transformation

Mileage	X	Y
DK113+020	4387915.123	500590.5459
DK113+030	4387913.956	500610.5119
DK113+040	4387912.789	500630.4778
DK113+050	4387911.623	500650.4437
DK113+060	4387910.456	500670.4097
DK113+070	4387909.289	500690.3756

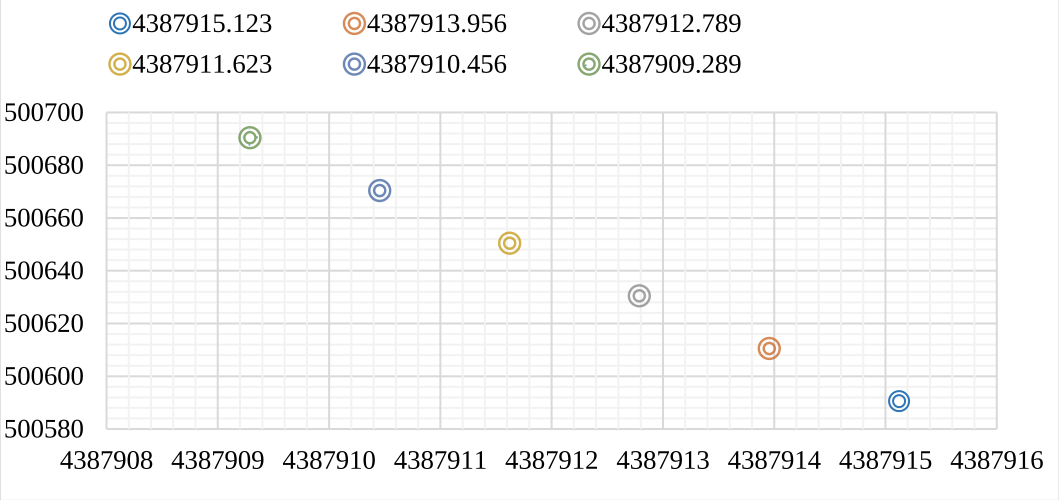


Figure 1: Coordinate Transformation

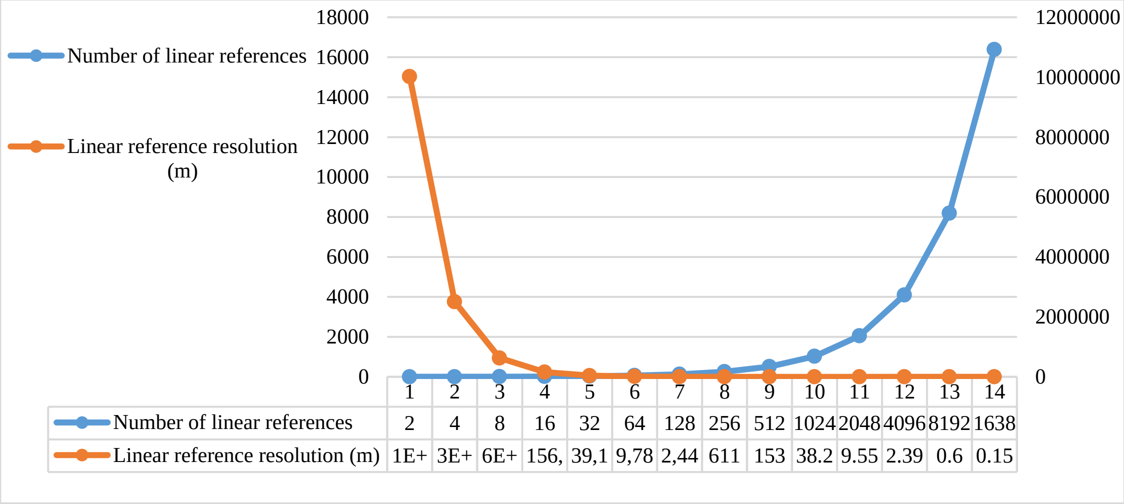
Mileage is the measurement unit with the most practical application value in the linear reference system. In order to better fit the data organization and visual expression of the line scene, the line and center mileage are often used to realize the accurate calculation of the mileage. At present, in the three-dimensional scene, the geographic coordinate system is generally used to define the position of the entity object. The linear scene has obvious band distribution characteristics, so the traditional coordinate system cannot better meet the business needs, so the one-dimensional linear coordinate came into being.

4.2. The Relationship between the Number of Linear Reference Divisions and the Number of References and Resolution

The corresponding relationship between the number of different linear reference divisions, the number of linear references, and the resolution of the linear reference is shown in Table 2:

Table 2: Linear reference division relationship

Number of divisions	Number of linear references	Linear reference resolution (m)
1	2	10018754.171395
2	4	2504688.542849
3	8	626172.135712
4	16	156,543.0339280625
5	32	39,135.758482
6	64	9,783.9396205
7	128	2,445.984905125
8	256	611.49622628125
9	512	152.8740565703125
10	1024	38.21851414257813
11	2048	9.554628535644531
12	4096	2.388657134033203
13	8192	0.5971642834472656
14	16384	0.1492910708618164



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Number of linear references	2	4	8	16	32	64	128	256	512	1024	2048	4096	8192	1638
Linear reference resolution (m)	1E+	3E+	6E+	156,	39,1	9,78	2,44	611	153	38.2	9.55	2.39	0.6	0.15

Figure 2: Linear reference division relationship

As can be seen from the above table, the number of linear references and the number of divisions are proportional to the linear reference resolution. The higher the number of divisions, the higher the linear referencing accuracy (linear referencing resolution). When the number of divisions reaches 15, the resolution is 0.037m (within 5 cm), which can meet most practical needs.

5. Conclusions

This paper establishes a three-dimensional simulation system of urban traffic through the research of urban traffic theory. The environmental background of the 3D simulation of urban traffic studied by this system is the simulation reproduction of the traffic flow under the premise of one or two intersections and traffic lights control. The main research is the relationship between vehicles and vehicles, between vehicles and traffic lights, and changes in the vehicle's driving lane, such as going straight, turning and other behaviors. The system is displayed in a three-dimensional animation. In addition, the video fusion technology is applied to the 3D simulation of urban traffic, the purpose is to superimpose and display the vehicle driving conditions in the real traffic video and the 3D vehicle model in the system in the same window in real time, so as to achieve the purpose of fusion. At the same time, an event-driven model is constructed, and the simulation of 3D line dynamic scene is realized by injecting attribute events, space events and business events.

References

[1] Mckane R G., Hess D J. Ridesourcing and urban inequality in Chicago: Connecting mobility disparities to unequal development, gentrification, and displacement: Environment and Planning A: Economy and Space, 2022, 54(3):572-592.
[2] Amsler Y. Reshaping urban mobility. Metro Report International, 2019, 33(1):4-5.
[3] Maria Diez J., Eugenia Lopez-Lambas M., Gonzalo H., et al. Methodology for assessing the cost effectiveness of Sustainable Urban Mobility Plans (SUMPs). The case of the city of Burgos. Journal of Transport Geography, 2018, 68(APR.):22-30.
[4] Anelkovi S., Ivanovi I. Implementation of GIS in sustainable urban mobility plans. Tehnika, 2020, 75(2):216-221.
[5] Vasconcelos E., Faria H M. Transformaes na mobilidade urbana em Curitiba sob a perspectiva metropolitana / Transformations in urban mobility in Curitiba from the metropolitan perspective. Brazilian Journal of Development, 2021, 7(6):63826-63845.
[6] F Almeida, Silva P., Leite J., et al. Proposal of a Carsharing System to Improve Urban Mobility. Theoretical & Empirical Researches in Urban Management, 2017, 12(3):32-44.
[7] Arhin S A., Gatiba A., Anderson M., et al. Improving Mobility on Segments with Closely Spaced Intersections in Urban Areas. Open Journal of Civil Engineering, 2019, 09(1):46-56.
[8] R?Th T., Pielen M., Wolff K., et al. Urban Vehicle Concepts for the Shared Mobility. Atz Worldwide, 2018, 120(1):18-23.

[9] Durrant C B., Begg J D., Kersting A B., et al. Cesium sorption reversibility and kinetics on illite, montmorillonite, and kaolinite. The Science of the Total Environment, 2018, 610-611(jan.1):511-520.
[10] Lim Y., Kim D., Jang J., et al. Adsorptive Removal of Cesium Ions Using Prussian Blue Immobilized Coffee Ground Biochar. Journal of Korean Society of Environmental Engineers, 2021, 43(5):336-346.
[11] Park J H., Kim B. Associations of Small Business Closure and Reduced Urban Mobility with Mental Health Problems in COVID-19 Pandemic: a National Representative Sample Study. Journal of Urban Health, 2021, 98(1):13-26.
[12] Chavez-Rodriguez L., Lomas R T., Curry L. Environmental justice at the intersection: exclusion patterns in urban mobility narratives and decision making in Monterrey, Mexico. Die Erde; Zeitschrift der Gesellschaft für Erdkunde zu Berlin, 2021, 151(2-3):116-128.