Cesium-MRS: A Cesium-based Platform for Visualizing Multi-source Remote Sensing Data

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ABSTRACT:

Remote sensing data is a primary means of obtaining information about the Earth's surface, widely used in various fields such as geographic information, natural resource management, urban planning, and environmental monitoring. However, due to the large volume and high complexity of remote sensing image data obtained from satellites, drones, and other equipment, efficient processing of this data and visualization of the results have become important issues. This paper presents a Cesium-based platform for visualizing multi-source remote sensing data, aimed at contributing to urban development efforts and providing additional insights for surveying education.This platform allows users to intuitively understand the spatial distribution and dynamic changes of remote sensing data. It not only integrates different types of remote sensing data into a unified 3D scene but also allows users to interact with the data according to their needs. A Cesium-based urban visualization platform was developed to display the geographic location of a specific region in Hong Kong and provide spatial measurement functions. This platform has wider applications in surveying and mapping education, as it can incorporate more remote sensing and geospatial data, allowing for increased student-teacher interaction and helping students better understand surveying and mapping concepts.Focusing on the construction of smart cities, the platform improves spatial awareness and interactivity for urban planning and management. Moreover, the platform has great potential in surveying and mapping education, providing a more immersive learning experience for students and cultivating talents in the field.

1. INTRODUCTION

As the economy and technology develop, more and more elements from urban and rural areas are being integrated. From environmental protection to urban greening, from traffic management to emergency response, from agriculture to industry, the complex and large number of elements have rapidly increased in the process of social progress, posing greater challenges and requirements for urban management and decision-making. The rapid development of the internet has made it possible to integrate these urban elements into information technology, simplifying urban management and planning[1].

With the support of national policies, "Digital Twin" cities are gradually developing. In 2022, Qingdao achieved high-precision land-sea real scene three-dimensional coverage, providing a detailed and unified digital space foundation for the construction of smart cities, which has promoted the leap from two-dimensional to three-dimensional GIS information[2]. Meanwhile, cities such as Xi'an, Shenzhen, and Shanghai have also put their initial real scene three-dimensional results into use. In addition, most of the basic surveying and mapping 14th Five-Year Plans actively released by provinces involve real scene three-dimensional, and these research results will play a significant role in research fields such as education,industry, agriculture, resources, and the environment.

(a) 3D Real Scene of Qingdao

(b) 3D Real Scene of Xi’an

(c) 3D Real Scene of Shenzhen

Figure 1. 3D Real Scene of the city[3]

Cesium is an open-source JavaScript library used for creating high-performance, cross-platform virtual globes and geographic information system (GIS) applications. It is based on WebGL and HTML5 and supports the visualization and interactive manipulation of 3D globes, satellite imagery, terrain, and vector data. Cesium's emergence has made it easier for developers to build high-quality earth science applications, thereby greatly advancing the development of virtual globe technology in various fields. Nowadays, virtual globe technology is increasingly widely applied, and with the continuous progress of geographic information technology and computer graphics, virtual globe technology has been widely applied in meteorology, agriculture, energy, and environment, and the emergence of the Cesium library has provided more efficient and flexible tools for the development of virtual globe applications.

A multi-source remote sensing data visualization platform built on Cesium is well-suited to the construction and development of digital cities and smart cities. The platform uses a real-world 3D city as its base, and comprehensively utilizes modern information technologies such as the Internet of Things, cloud computing, and big data to integrate multi-source data information and present city information in a more easily understood 3D manner, such as displaying city 3D real scene data, measuring city space distance, area, and triangle measurements, etc. This will play an important role in promoting the reform of the urban management system and accelerating the upgrade of digital city management to smart city management[4]. At the technical level, the platform has improved data visualization effects, integrated multi-source data, and improved the efficiency of 3D data analysis, providing comprehensive and reliable technical support for the sustained development of society.

Numerous projects abroad have been built on Cesium to develop multi-source remote sensing visualization platforms. The Singapore Urban Redevelopment Authority (URA) has developed a digital earth platform using Cesium to visualize the planning and development of Singapore. The platform displays various aspects of the city, including land use, transportation, buildings, and facilities, to help policy makers, urban planners, and the public better understand the city's development. Additionally, the Singapore government funded the construction of Virtual Singapore using Cesium, which presents Singapore's geographic spatial data, including information on buildings, roads, and transportation. Smart Dubai, a digital earth platform funded by the Dubai municipality, displays information on Dubai's buildings, transportation, public facilities, and natural environment, and is used for urban planning, tourism, and safety monitoring. Los Angeles has also created the Los Angeles Open Data Portal, built on Cesium, to showcase various aspects of the city, such as transportation, crime rates, and land use. Many platforms built on Cesium are already in operation abroad and play an important role as technological support in urban management and planning.

Traditional data visualization methods are typically two-dimensional, which can be limited when presenting three-dimensional scenes and geospatial data that require multidimensional display. Additionally, there are limitations to interactive functions[5]. This article attempts to build a multi-source remote sensing data visualization platform based on Cesium, combining web and GIS technologies to provide a solution to the spatial limitations of traditional data when presenting multidimensional displays in three-dimensional scenes and geospatial data. This article completes the following tasks:

(1) Obtaining and converting oblique photography models.

(2) Geospatial data visualization, including loading three-dimensional scenes and visualizing spatial positions such as longitude, latitude, elevation, camera height, and scale.

(3) Spatial measurement function, including "spatial distance", "spatial area", "triangulation", and "clear measurement".

(4) Exploration of Educational Applications. In the field of surveying and mapping education, the platform can facilitate more interaction between teachers and students, enhance students' experience in surveying and mapping disciplines, and cultivate more talents for the surveying and mapping industry.

2. METHODOLOGY

This paper focuses on the display of multi-source data and investigates the processing and format conversion methods of oblique photogrammetry model data. The data is then presented and spatially measured on a platform built with Cesium. Before constructing the platform to display the data and related interactive operations, relevant environmental deployment, Cesium source code acquisition, and installation are necessary. The detailed technical process is shown in the figure.

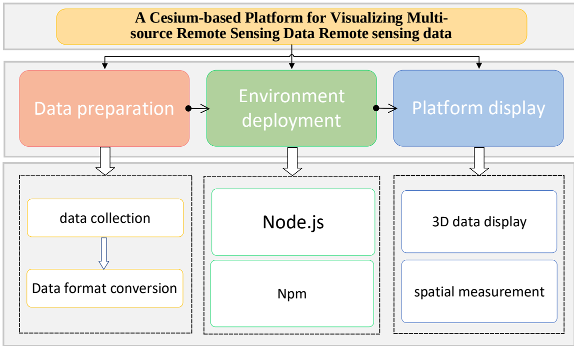


Figure 2. Workflow of proposed Cesium-based 3D display method

Cesium is a JavaScript-based WebGL engine for visualizing 3D Earth and maps, suitable for developing a variety of 3D map applications. It was formally proposed by Patrick in 2014 and has been used to render world-class 3D globes and maps, allowing users to build 3D scenes by adding and manipulating various entities, including the Earth, buildings, aircraft, and more, through thousands of lines of open-source code[6]. The CesiumJS ecosystem now includes thousands of developers and millions of users, with millions of downloads, making it more widely used.

In addition to its open-source features, Cesium also supports cross-platform operation, can run on various computers and mobile devices, and supports multiple operating systems. It has dynamism, can display complex 3D geospatial data, and provides real-time data updates and interactivity. It is scalable, supporting multiple formats of geospatial data and can be integrated with other GIS and web development tools. It is user-friendly, with a friendly interface and good documentation, which can help users quickly get started and create their own map applications.

Regarding data transmission, Cesium supports loading and processing of various data formats, including GeoJSON, KML, 3D Tiles, and more, which can help developers quickly display geospatial data in 3D scenes. Additionally, Cesium provides a range of APIs and plugins that can help developers achieve various custom functions and extensions.

In the official documentation of Cesium, all classes and their usage are explained, as shown in Table 1. Here, we only briefly describe several key classes:

(1) Cesium.Viewer: This is the main entry point for creating a Cesium Earth. It is responsible for creating and managing components such as scenes, cameras, and the ellipsoid of the Earth, and provides some default settings. The Earth's various features and effects can be implemented by configuring the properties and methods of the Viewer.

(2) Cesium.Entity: This class represents entities in the scene, such as landmarks, trajectories, and sensors. The position, direction, appearance, animation, etc. of the entity can be controlled by configuring its properties and methods.

(3) Cesium.DataSource: This class is used to load and process various data sources, such as KML, GeoJSON, CZML,

3D Tiles, GLTF, etc. The loading mode, parsing mode, rendering mode, etc. of the data source can be controlled by configuring its properties and methods.

(4) Cesium.Camera: This class is used to represent the camera in the scene, including properties such as position, orientation, and field of view. The camera's viewpoint, movement, scaling, etc. can be controlled by configuring its properties and methods.

(5) Cesium.ScreenSpaceEventHandler: This class is used to handle screen-space events such as mouse clicks, drags, and scrolls. Custom interaction operations can be implemented by configuring the callback functions of the ScreenSpaceEventHandler.

Table 1. Key Classes in Cesium

Cesium Classes	Main parameters
Viewer	terrainProvider, imageryProvider, sceneMode, animation, baseLayerPicker, homeButton etc.
Entity	Position, Orientation, Model, Label, Billboard, Path, Polygon etc.
DataSource	isLoading, show, Clock, modelMatrixclampToGround etc.
Camera	Position, Direction, Up, Frustum, Viewport, defaultMoveAmount, defaultLookAmoun etc.
ScreenSpaceEventHandler	leftClick, leftDoubleClick, rightClick, mouseMove, pinchEnd, touchEnd etc.

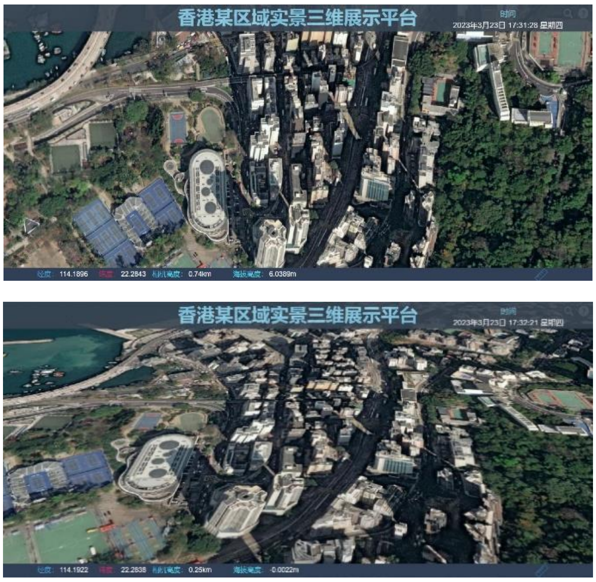
However, the formats of photogrammetric 3D real scene data are generally limited to OSGB, OBJ, FBX, STL, 3DS, which cannot be loaded in Cesium. This article uses obtained OSGB format data to illustrate the differences between the formats supported by Cesium and OSGB format.

OSGB format stands for OpenSceneGraph binary data format, which is a relatively limited format that can only be used for rendering and displaying with OpenSceneGraph software. Compared to OSGB, 3DTiles format is more flexible and universal, more suitable for scene rendering and visualization[7]. 3DTiles is a data format for large-scale scenes that can transform complex geographical information into interactive 3D models, while supporting efficient streaming loading and rendering, and suitable for various platforms and devices.

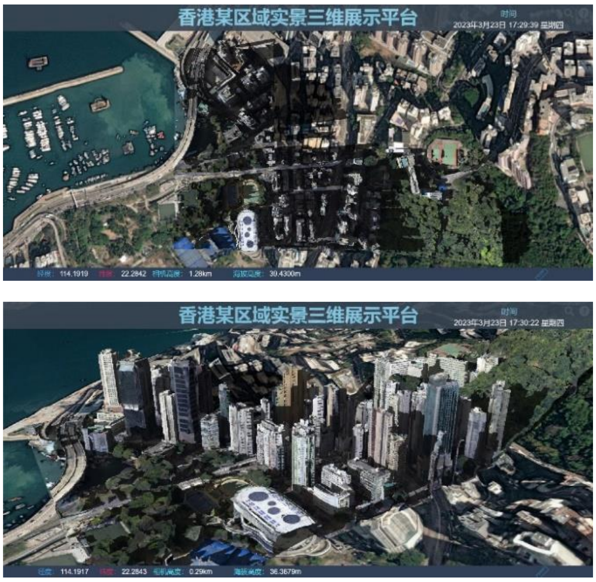
The difference between the two lies in that 3DTiles format is an open data format that can support various types of data sources and provides flexible specifications and interfaces for easy secondary development and customization. In contrast, OSGB format is a closed file format that can only be rendered and displayed with specific software and cannot be extended or customized. In addition, 3DTiles format also supports dynamic data and multi-level details, which can better display and interact with complex scenes, while OSGB format can only display static data.

3. DATASET AND EXPERIMENTS

The 3D model of the large-scale urban reality can be obtained by aerial photogrammetry and aerospace photogrammetry[8-10]. This paper uses a 3D model generated by aerial photogrammetry(https://www.pland.gov.hk/pland_sc/info_serv/3D_models/download.htm). The process of generating the model involves computing the three-dimensional point cloud of objects and constructing a mesh, and then applying texture technology to generate the model in OSGB format. After format conversion, a realistic 3D model in 3DTiles format supported by Cesium is generated.The models are then loaded into the 3D real scene by calling the add method of primitive. As the correct coordinate information has already been set during the process of generating 3D Tiles files, manual adjustment of the model's position is unnecessary after it is loaded. When visualizing the model, the zoomTo method or camera position setting method can be used to adjust the viewpoint to the model's position. The specific effects are shown below.



(a) 2D map visualization



(b) 3D map visualization

Figure 3. Comparison of 2D and 3D visualization effects (a and b)

To build a visualization platform based on Cesium, environment deployment will be conducted prior to platform construction, including installation and configuration of Node.js and npm, as well as installation of Cesium source code.

Node.js is an open-source JavaScript runtime environment that can be used for developing server-side applications. It allows for the seamless connection between front-end and back-end through the use of JavaScript, which is a great advantage. Node.js was initially developed by Ryan Dahl to achieve high-performance network applications, and it is built on Google's V8 JavaScript engine. V8 is a high-performance JavaScript engine that can convert JavaScript code into machine code, giving Node.js excellent performance and efficiency. Since npm has been integrated into Node.js, there is no longer a need to install it separately via cmd. The latest version of Node.js is currently 18.15.0.

The spatial measurement feature is implemented through four buttons labeled "Spatial Distance," "Spatial Area," "Triangle Measurement," and "Clear Measurement." Left-clicking the mouse adds points, while right-clicking ends the process, and the system automatically calculates the spatial distance or area. Clicking "Clear Measurement" removes the drawn lines, polygons, and displayed area and distance measurements. Taking "Spatial Distance" and "Spatial Area" as examples, the implementation strategy for this feature is as follows:

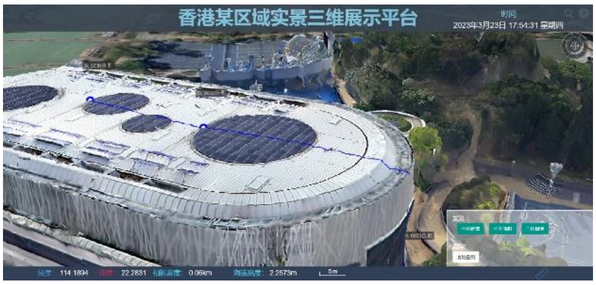


Figure 4. Spatial distance measurement

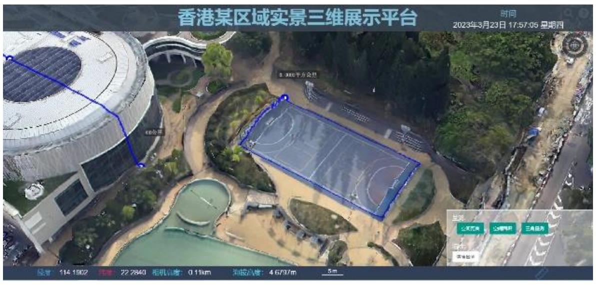


Figure 5. Space area measurement

4. APPLICATION IN EDUCATION

This paper employs the "add" method of the Cesium primitive to load real 3D data and successfully realizes spatial measurements of real scenes. In practical applications, this not only plays a role in smart city construction, but also stimulates students' interest and enthusiasm for classroom content or programming through the display of 3D scenes. For example:

(1) In the teaching of geography, real geographic and terrain data such as topography and climate can be loaded using Cesium. This can help students better understand the physical properties of the earth and its interaction with humans, allowing them to more intuitively grasp knowledge related to the earth's landforms, climate, natural resources, and other aspects.

(2) In interactive teaching, the Cesium platform supports user interaction, and teachers can use the platform to create multiple markers, annotations, or paths to guide students in completing tasks or solving problems.

(3) In the teaching of science courses, Cesium can load satellite data to display scientific concepts and knowledge to students. For example, the platform can demonstrate actual phenomena such as meteorological changes, ocean currents, and environmental pollution, helping students better understand scientific knowledge.

The above examples can all be achieved through the Cesium platform, which can assist students in better comprehending and exploring the real world in future surveying and mapping education. This platform promotes the visual, auditory, and motor development of students, stimulates their interests and curiosity, and improves their learning outcomes. Additionally, it can help to cultivate more talented individuals in the field of surveying and mapping.

5. CONCLUSION

This paper focuses on the construction of smart cities and proposes a platform based on Cesium multi-source remote sensing data loading, which enables the loading of 3D realistic models and spatial measurements. By comparing the visual effects of 2D maps and 3D scenes, the advantages of 3D GIS visualization technology over 2D GIS technology can be perceived from a visual perspective, which effectively solves the problems of the single display mode, low spatial cognition, and few interactive methods of 2D visualization when displaying 3D spatial data.

Although this paper has achieved some results in data display and spatial measurement, there are still shortcomings that need to be further studied. In the future, it is necessary to continue to improve the platform to adapt to the needs of urban construction, including improving the accuracy of model acquisition and processing by using close-range measurement of unmanned aerial vehicles, focusing on the quality of data collection, and improving the accuracy of models. Additionally, the real-time transmission and data analysis of urban construction management are important research topics, and the 3D analysis module of the platform needs to be expanded to meet practical demands.

Moreover, this paper lists some specific application scenarios of platforms in classroom teaching in surveying and mapping education. It is a bold and innovative hypothesis that, in current education settings in China, whether in secondary or university education, there is an urgent need to add more intuitive and interesting teaching methods. This not only means upgrading the form of education but also changing the way of education. By experiencing more "realistic" learning, students can increase their learning interest and understanding. Finally, this paper will continue to delve into research and explore more platform development directions for surveying and mapping education.

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