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Indoor Map Construction Methods for Indoor Location Services

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ABSTRACT

This study proposes a hybrid map model integrating building entity elements with network topology structures, addressing the challenges of constructing building map models in complex and dynamic geographical environments. Using Building Information Modeling (BIM) as the core data source and leveraging Geographic Information System (GIS) integration principles, the model synthesizes both geometric/attribute data of buildings and dynamic geospatial environmental variables. Building upon this hybrid model, we further design and implement an engine-based scheduling and loading framework optimized for building maps. The solution enables efficient cross-platform loading (web and mobile clients), ensuring seamless user access and interaction with building maps across diverse devices. This approach significantly enhances the accessibility and practical utility of map applications.

KEYWORDS

Entity Model; Network Model; Hybrid Model; 3D Model Visualization

1. INTRODUCTION

The development of indoor positioning and navigation has garnered significant attention from Chinese national authorities, with a series of policies enacted to promote its applications in daily life and industrial production. In March 2021, the State Council introduced the *14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives Through 2035*, advocating digital "single-map" management of urban buildings, public spaces, and underground pipelines. Subsequently, in September 2021, eight ministries including the Ministry of Industry and Information Technology (MIIT) and the Ministry of Housing and Urban-Rural Development (MOHURD) issued the *Three-Year Action Plan for New IoT Infrastructure Construction (2021–2023) *, calling for advances in low-power, high-security, high-speed short-range communication technologies, alongside R&D in highly reliable BeiDou positioning and high-precision indoor positioning systems. Further, in January 2022, MIIT released the Guidelines on Promoting BeiDou Applications in Consumer Markets, emphasizing breakthroughs in seamless indoor-outdoor positioning technologies integrating satellite, base station, and sensor data. In February 2022, the State Council's *14th Five-Year National Emergency Response System Plan* highlighted the use of digital technologies in disaster management, including personnel search and object localization. Concurrently, rapid economic growth has spurred the construction of large-scale complexes (e.g., hospitals, shopping malls, and transportation hubs), driving demand for indoor location-based services across fields such as healthcare, emergency monitoring, and public safety.

To date, the complexity and variability of indoor architectural environments have made it difficult for existing building maps to meet the refined and diverse demands of universal applicability.

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Achieving high-precision indoor map construction to provide a robust data foundation for indoor location-based services has emerged as a critical scientific and technological challenge requiring urgent breakthroughs. Current indoor mapping methodologies are in pressing need of innovation.

2. RELATED WORK

Research on building maps in China primarily focuses on the integration of BIM and GIS, with key efforts directed toward lightweight IFC schema conversion, indoor semantic extension of CityGML, and vector-raster integrated navigation models. As an open standard for 3D urban model data exchange, CityGML has been widely adopted for the modeling and management of entity models. The CityGML 2.0 specification defines five levels of detail (LOD0 to LOD4), enabling precise representation of urban features from macro to micro scales. As noted by Gröger et al. [1], CityGML not only supports building modeling but also accommodates diverse urban objects such as bridges, tunnels, and roads, demonstrating high flexibility and extensibility. However, as applications expand, CityGML has revealed certain limitations in handling complex interior structures of buildings. To address this, Biljecki et al. [2] proposed an enhanced LOD specification to better adapt to intricate architectural modeling requirements. In the process of entity model construction, data conversion tools play a critical role. The Feature Manipulation Engine (FME), a powerful spatial data transformation platform, efficiently converts IFC data into CityGML format while supporting interoperability across multiple file formats and databases. Leveraging FME, Lam et al. [3] achieved the conversion from IFC to CityGML LOD4 and realized 3D urban model visualization through platforms such as Cesium and Unreal Engine (UE).

A network model represents a specialized data structure that facilitates the execution of path planning algorithms. Currently, two primary navigation models dominate the field: vector-based network models and raster-based network models [4], corresponding to vector and raster representations respectively. Based on their construction methodologies and visualization outcomes, vector network models can be further classified into three categories: visibility graph-based approaches, straight skeleton-based approaches, and Voronoi diagram-based approaches.

The concept of grid-based networks was first proposed by W. E. Howden [5]. Its fundamental principle involves partitioning a planar environment into discrete grid cells, with each cell assigned a specific value to indicate its traversability. On this basis, a connectivity graph comprising only free (traversable) grid cells is constructed to identify collision-free paths from a start cell to a target cell. The final path is then generated through the application of relevant algorithms [6, 7].

3. METHODOLOGY

3.1. Entity Model Construction

Current entity models for representing indoor architectural elements primarily fall into two categories: geometric boundary models and architectural entity models. Geometric boundary models are constructed by capturing spatial boundaries, using volumetric shapes to represent indoor spatial units. In contrast, architectural entity models are typically generated from 2D floor plans or constructed via 3D modeling software. Compared to geometric boundary models, architectural entity models provide more precise representations of indoor structural configurations and deliver superior visual realism for end-users. Therefore, this study adopts the architectural entity model approach [8].

The construction of entity models involves numerous complex components. To facilitate systematic management and organization, this study categorizes these components into three groups: basic elements, identifier elements, and thematic elements (Table 1).

Basic elements form the core framework of building maps, including walls, columns, doors, windows, floors/ceilings, and staircases. These elements feature relatively simple textures and are typically generated by converting 2D data into 3D models.

Identifier elements possess distinctive characteristics that serve as anchors for building feature localization, such as doorplates, display boards, digital screens, and floor indicators. Their texture information must align with their identifiable features and requires integration of both photographic references and geometric data.

Thematic elements are non-essential components that can be added based on application-specific needs (e.g., library bookshelves or seating). The level of texture detail for these elements is customizable, though they similarly require combined image-geometry modeling.

Table 1. Classification and Characteristics of Entity Model Components [6]

Element Type	Included Components	Texture Complexity	Construction Method	Application Scenario
Basic Elements	Walls, columns, doors, windows, floors, etc.	Low (simple geometry)	3D modeling from 2D data	Architectural structure representation
Identification Elements	Door plates, display boards, screens, etc.	High (requires image matching)	Combined geometric + image construction	AR enhancement, positioning markers
Thematic Elements	Bookshelves, seats, etc.	Medium (adjustable as needed)	Added based on requirements	Scene customization

3.2. Network Model Construction

The road network is constructed following a systematic methodology of "primary structure first, details later; horizontal levels first, vertical connections next". The process begins with establishing the overall layout by connecting the central points of corridors on each floor to form the fundamental skeletal structure for individual levels. Subsequently, detailed pathways are created by linking all target nodes within the floor to these corridor center points, completing the horizontal network. Finally, vertical connectivity is achieved by interconnecting access nodes (e.g., stairwells, elevators) across different floors, ultimately forming a comprehensive 3D navigation network for the entire building [9].

3.3. Hybrid Model Construction

The hybrid model incorporates two fundamental connection types: direct connections and indirect connections. Direct connections establish explicit correspondences between two models without intermediary components, while indirect connections require intermediate models to bridge relationships between non-corresponding elements.

4. EXPERIMENTS AND DISCUSSION

4.1. Experimental Data

This study selects two representative case studies:

(1) Surveying and Mapping Building F (116.29°E, 39.75°N) - A six-floor office building featuring characteristic elongated corridor layouts and semi-regular structural element distributions, serving as a typical institutional architecture case;

(2) Beijing University of Civil Engineering and Architecture (Daxing Campus) Library (116.34°E, 39.67°N) - An eight-floor complex (7 above-ground + 1 basement) with expansive interior spaces and intricate structural configurations, representing challenging open-plan environments.

4.2. Experimental Results and Analysis

4.2.1. Mobile-Oriented Positioning and Navigation System

The mobile indoor positioning and navigation system was implemented in Building F of the Surveying and Mapping College at Beijing University of Civil Engineering and Architecture as a practical application scenario. Its core functionalities encompass four main modules: floor display, indoor positioning, path planning, and scene navigation.

The system's main interface presents a 3D model of the building, allowing users to perform intuitive screen interactions such as zooming in/out, rotating, and selecting specific floors. Upon selecting a particular floor, users can access the interior view to obtain detailed floor information, as shown in Figure 4-1(a).

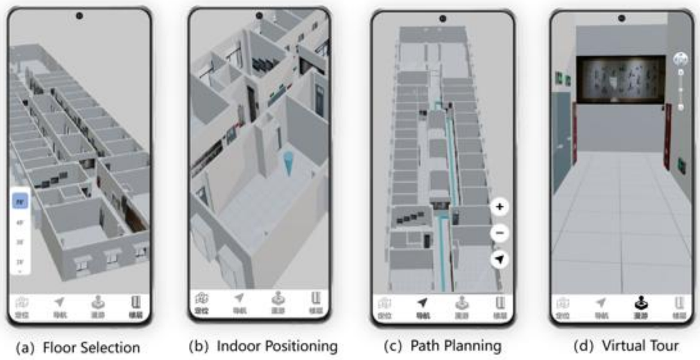

Figure 1. System interface

When the user enters the building model, the system integrates data from the smartphone's built-in sensors with its proprietary positioning algorithm to acquire real-time location data. This information is then dynamically linked with the building map database and visualized as a positioning marker, enabling real-time indoor localization functionality as demonstrated in Figure 4-1(b).

Within the map interface, users may select a destination to trigger the system's multi-path planning algorithm. The interface displays multiple route options, with Figure 4-1(c) showing the visual representation of a selected path. Users may then activate the navigation mode to experience immersive wayfinding guidance, illustrated in Figure 4-1(d).

4.2.2. Web-based 3D Visualization and Analysis System

The 3D visualization system is developed based on the hybrid building map model, incorporating advanced visualization technologies to establish a web-oriented 3D building visualization and analysis system. This system has been primarily deployed at the Library of Beijing University of Civil Engineering and Architecture (Daxing Campus). The system architecture comprises two core modules:

(1) A WebGL-based 3D building visualization platform, which employs open-source 3D libraries to render building models and provides fundamental spatial manipulation functionalities.

(2) An information scheduling and management module designed specifically for handling the library's massive datasets, implementing specialized functions tailored to library application scenarios.

The main interface of the 3D visualization and analysis system consists of a 3D model display area, a side data panel, and a bottom toolbar. The toolbar provides functions such as reset, distance measurement, angle measurement, and floor selection, as shown in Figure 2. Additionally, users can perform basic operations on the 3D model—such as panning, rotating, and zooming—using the mouse. The specific functionalities are introduced as follows:

Figure 2. System interface

(1) Component Tree

The component tree organizes, manages, and displays the hierarchical structure of elements in the Building Information Model (BIM), including detailed attribute information and relationships between components. Users can intuitively navigate and inspect individual elements, enabling quick access to areas of interest.

(2) Length Measurement

Users can select measurement regions via mouse clicks or drag operations to calculate the straight-line distance between two points, as well as the projected distances along the X, Y, and Z axes (see Figure 3).

Figure 3. Length measurement function

(3) Angle Measurement

This feature allows users to select specific regions for measurement by clicking or dragging with the mouse, facilitating convenient angle measurements to meet their objectives (see Figure 4).

Figure 4. Angle measurement function

(4) Floor Selection

The floor selection function enables users to quickly locate and navigate different floors within the building's internal map. Through an intuitive interface, users can seamlessly switch between floors. Detailed information for each area is displayed on the map using symbolic representations, enhancing the user's understanding of the building's layout and structure (see Figure 5).

Figure 5. Floor selection function

(5) Click Interaction Event

Click interaction allows users to engage with the building model through simple mouse clicks. When the cursor hovers over a specific floor and clicks on a feature symbol, the system responds by displaying detailed information related to that area. This intuitive interaction improves information retrieval efficiency and enhances the user experience (see Figure 6).

Figure 6. Information Enquiry Function

(6) Reset

The reset function restores the interface to its initial state or default settings. Executing this operation clears all prior custom modifications, allowing for rapid repositioning of the building model (see Figure 7).

Figure 7. Reset function

5. CONCLUSIONS

This study successfully developed a hybrid map model integrating Building Information Modeling (BIM) and Geographic Information Systems (GIS), combining entity elements and network topology structures. This approach effectively addresses the challenges of accuracy and efficiency in map construction for complex indoor environments. Experimental results demonstrate that the model achieves efficient loading and visualization on both mobile and web platforms, supporting functionalities such as indoor positioning, path planning, 3D visualization, and interactive analysis, thereby significantly enhancing user experience and application value. The research outcomes provide a reliable data foundation and technical support for indoor location-based services (LBS), laying a critical groundwork for future advancements in smart city development and indoor navigation services.

REFERENCES

[1] Groger, G., Kolbe, T.H., Nagel, C., et al. (2012). OGC City Geography Markup Language (CityGML) Encoding Standard. Open Geospatial Consortium. https://docs.ogc.org/is/21-006r2/21-006r2.html

[2] Biljecki F, Ledoux H, Stoter J .An improved LOD specification for 3D building models [J]. Computers, Environment and Urban Systems, 2016, 5925-37. https://doi.org/10.1016/j.compenvurbsys.2016.04.005

[3] Lam D P, Gu H B, Lam K H, et al. Digital Twin Smart City: Integrating IFC and CityGML with Semantic Graph for Advanced 3D City Model Visualization [J]. Sensors (Basel, Switzerland), 2024, 24(12):3761-3761. https://www.mdpi.com/1424-8220/24/12/3761

[4] H. Bo, Y. Guanghui, L. Xun, et al. Research on indoor positioning and navigation system based on indoor map [J]. Geomatics Technology and Equipment, 2024, 26(03): 9-13. DOI: 10.20006/j.cnki.61-1363/P.2024.03.002.

[5] T. W. Shao. Improvement of Path Planning Algorithm Based on Grid Map and Implementation of 3D Visualization System [D]. Hebei University of Engineering, 2023. DOI: 10.270104/d.cnki.ghbjy.2023.000699.

[6] You T, Wang G X, Lyu X H, et al. A passable area model for indoor navigation and its automatic extraction algorithm [J]. Geomatics and InformationScience of Wuhan University, 2019, 44(02): 177-184. DOI: 10.13203/j.whugis20170056.

[7] Ran N, Zhang J M, Yang H F, et al. AGV path planning algorithm based on semantic segmentation network [J]. Journal of Electronic Measurement and Instrumentation, 2023, 37(07): 121-130. DOI: 10.13382/j.jemi.B2306301.

[8] Luo J Y. Research on construction method of building reality holographic map model [D]. Beijing University of Civil Engineering and Architecture, 2021. DOI:10.26943/d.cnki.gbjzc.2021.000156.

[9] Jianhua L, Jingyan L, Jiwei H, et al. A BIM Based Hybrid 3D Indoor Map Model for Indoor Positioning and Navigation [J]. ISPRS International Journal of Geo-Information, 2020, 9(12):747-747. https://www.mdpi.com/2220-9964/9/12/747