Proceedings of the 4th International Conference on Signal Processing and Machine Learning
DOI: 10.54254/2755-2721/53/20241313

Research on a community life route guidance system based on virtual reality technology

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Abstract. Virtual reality technology holds significant potential for applications in the field of urban visualization, although it is primarily utilized for showcasing architectural forms or aiding in planning and design processes. To enhance the integration of urban visualization technology into the everyday lives of ordinary residents and expand the user base beyond planners, this paper introduces the ‘Community Life Route Guidance System’, leveraging the presentation of ‘economic livelihood’ to afford residents interactive experiences within authentic living scenarios. By incorporating and aligning the location and information of Points of Interest (POIs) within the urban model of a single community and its surrounding neighborhoods, it generates, calculates, and filters 'life routes' comprising four categories of commercial nodes. The objective is to serve new residents in the community by providing life guidance or to offer prospective homebuyers a reference point for the convenience of community commercial facilities. The specific technical pathway encompasses: constructing an environmental model, processing and associating POI data, life path identification based on the Dijkstra algorithm, and path visualization with user interaction.

Keywords: City visualization, Community, Information services, Path-finding algorithm.

1. Introduction

Virtual reality technology constructs a realistic, visual, tangible, and auditory virtual environment through computers. While showcasing simulated scenarios, users can interact within the virtual environment using interactive devices [1]. In the field of urban planning, virtual reality technology assists users in comprehensively obtaining spatial information, including buildings, landscapes, roads, facilities, etc., based on their cognitive abilities within the virtual environment. It is precisely due to this characteristic that virtual reality technology has significant applications in the field of urban planning, and simulation technology has become an essential foundation technology urgently needed in urban planning.

Based on the high applicability of virtual reality technology and its efficiency in conveying spatial information, it has a broad range of service scenarios in the field of urban visualization. This paper presents a community life route guidance system based on virtual reality technology, which is applied interactively to residents' life guidance and housing selection for individual urban communities. Taking the Wangzhuang Road community in Wudaokou Street, Haidian District, Beijing, as an example, this system utilizes nearby points of interest (POI) data in the community. It supplements the display of "building forms" with economic life demonstrations, generates, computes, and filters "life routes" encompassing four categories of commercial outlets: "shopping, dining, living, and leisure." Its specific technical path includes environment modeling, processing of POI data, life path recognition, path visualization, and navigation. This system offers insights into addressing the interactivity and serviceability of virtual reality technology in the current stage of urban planning and presents possibilities for practical use in small-scale urban visualization for residents.

2. Related work

Current research indicates that virtual reality technology has been widely applied in two aspects of urban and rural planning: firstly, the deduction of urban models based on cellular automata, organized to support basic geographical data[2]; secondly, planning performance display, dedicated to reflecting urban architectural landscape characteristics with high precision using Are GIS Engine components and OSG-integrated rendering models for assisting in planning design and management approval[3]. The prospects of virtual reality technology in urban planning and design research are promising, with the main parts being summarized as follows: the urban deduction field (interdisciplinary research on urban development mechanisms and theoretical and methodological research on multi-source data assimilation) and the urban visualization field (Urban planning models driven by remote sensing data and dynamic visualization of planning schemes)[4-5].

Regarding the two characteristics of high fidelity and high interactivity of virtual reality technology, existing research and applications, whether focusing on data analysis or performance display, mostly concentrate on the former. However, the design and development of "highly interactive" services based on virtual reality technology not only help fill this gap but also expand its application scenarios from planning managers to urban residents, thereby enhancing people's understanding and participation in the urban planning process.

3. Introduction to the system and technological workflow

3.1. Service logic and function introduction

The "Virtual Reality-Based Community Life Route Guidance System" is designed for urban communities. It uses commercial data to simulate residents' daily consumption routes, offering guidance to newcomers and prospective home-buyers. This allows them to assess architectural aesthetics and convenience through virtual reality. This not only enables them to view the architectural aesthetics of their residential environment through existing virtual reality products but also allows them to experience and assess its convenience for daily living.

The system includes virtual models encompassing 1 to 2 city blocks within the community and its vicinity, covering an approximate area of around 1 km^2. This aligns with the fundamental principles of the '30-minute non-essential life circle' as outlined in Beijing's urban planning [6]. Residents of the community typically access basic life services and make consumption choices within this model's range. These life and consumption choices are documented and manifested through the location records of Points of Interest (POI) data.

By extracting and categorizing POI data, including coordinates and names, they are linked to positions in a virtual model. These POIs, represented by Unity game objects, guide the creation of 'life routes'. Each 'life route' consists of five locations, starting from the 'community entrance' and sequentially passing through four POI locations, categorized as 'shopping (including daily necessities markets, vegetable markets, clothing retail, etc.)', 'dining (including restaurants, cafes, beverage shops, etc.)', 'recreation (including urban parks, amusement areas, internet cafes, cultural and creative shops, handmade shops, etc.)' and 'life (including beauty and hairdressing shops, etc.)'. These categories encompass essential and luxury services, offering a comprehensive path for residents to meet their daily needs from home.

Path generation is based on Dijkstra's algorithm. After implementing certain UI development, users can interact with paths, engage in directed roaming along the paths, and perform basic functions such as changing perspectives. This system is designed to run on Hololens virtual reality devices.

3.2. Technical workflow

The technical workflow of the system includes the following steps: the construction of a virtual environment model, the processing of Points of Interest (POI) data, the recognition of "life routes" incorporating shortest path selection, and path visualization and navigation.

The construction of the virtual environment model encompasses the acquisition of open-source models with elevation data and subsequent detailed processing. Taking the Wangzhuang Road community in the Wudaokou Street of Haidian District, Beijing, as an example, it covers four blocks intersected by the east-west roads "Chengfu Road" and the north-south roads "Heqing Road" and "Wangzhuang Road", totaling an area of 0.85 square kilometers of street building area. As shown in Figure 1, The detailed addition of building models and the supplementation of street greenery are performed using the Magiz plugin in Sketchup.

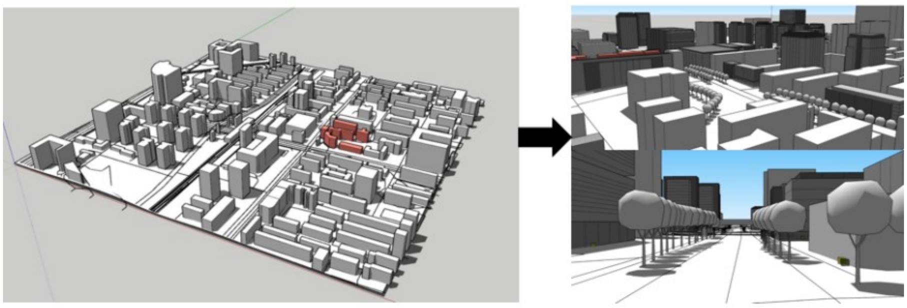

Figure 1. The community-centered city model, and its addition of details

In the designated block area, a five-step process was employed to collect, filter, categorize, map, and match Point of Interest (POI) data. Initially, 284 POI data points were collected, but after excluding non-relevant categories like "government," "medical," and "school," 91 POI points within the research scope were selected. These points were further categorized into "shopping," "dining," "daily life," and "leisure," with 34, 17, 8, and 32 points in each category, respectively. Latitude and longitude coordinates from these categories were imported into ArcGIS software for precise cartographic representation, involving the creation of small squares within the layers to accurately depict each POI point's position.

In the generation and recognition of "life routes," the shortest path algorithms through four categories of POI points, were respectively applied, with a primary emphasis on the Dijkstra algorithm and its principles. The Dijkstra algorithm, proposed by Dutch scientist Edsger W. Dijkstra in 1959, is a single-source path algorithm used to find the shortest paths in a graph by iteratively identifying the closest vertex to the source and performing relaxation operations [7].

In this research, excessively long and convoluted routes that do not align with the actual movement patterns of residents are not considered. The Dijkstra shortest path algorithm effectively serves the purpose of filtering out excessively long paths and selecting routes that better align with the practical choices of residents in their daily lives.

The algorithm operates in several key logical steps. Initially, it categorizes all vertices into two sets: 1) vertices with known shortest paths from the source vertex, and 2) vertices with unknown shortest paths. It initializes the distance from the source vertex to itself and sets distances to infinity for vertices inaccessible from the source. Subsequently, it includes the source vertex in the known set and commences node traversal, beginning at the object's initial location. The algorithm iteratively explores the unknown set, examining nodes in the to-be-checked node set and adding closest unreached nodes. This process continues until the unknown set is empty, ensuring path discovery from the initial to the target point. Finally, the algorithm assesses for unconverged vertices between the source and unknown set. If any exist, a relaxation operation is executed [8].

In this study, we examine spatial optimization within four categories: "shopping," "dining," "living," and "leisure," containing 34, 17, 8, and 32 points of interest (POI) respectively, select one POI from each

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category and calculate the shortest path starting from the entrance of Wangzhuang Road Community. To optimize path length, we should initially sort the selected points based on proximity to the starting point. Dijkstra's algorithm, which systematically explores the graph from the starting point, suits this task. Before applying the pathfinding algorithm, we use a combination algorithm to generate candidate combinations of one POI from each category, subsequently applying the modified pathfinding algorithm to these combinations.

In the traditional Dijkstra algorithm, only one distance array needs to be maintained to record the shortest distances from the starting point to each vertex. However, to calculate the shortest path passing through four points sequentially, it is necessary to add and maintain multiple distance arrays, each corresponding to a target point [9]. This study extends the priority queue of Dijkstra's algorithm, introducing nested logic to select the next node to be explored based on the number of target points reached, and performs backtracking after finding the shortest path.

In applying the algorithm to a virtual model, defining the source point library for the Dijkstra algorithm is vital, achieved by delineating residents' viable walking zones. As shown in Figure 2, using a 3D Cartesian coordinate system from land parcel edges, areas with buildings, identified via laser scanning, are marked "infeasible walking areas," while the rest are marked "feasible walking areas." These 91 designated POI game objects are placed in "feasible walking areas" for path-finding algorithm utilization.

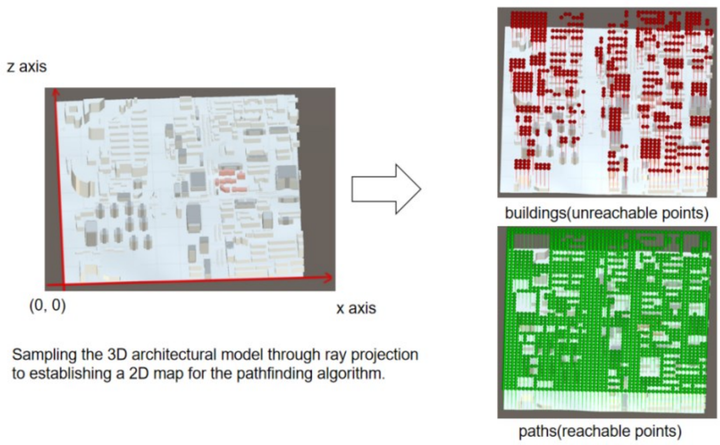

Figure 2. Defining the source point library by laser scanning

The final path-finding effect is shown in Figure 3. Through UI development, this project can realize interactive functionalities for users, including route selection, perspective transformation, path visualization, directed roaming and navigation, as well as textual information retrieval for Points of Interest (POI). Following deployment, the project serves a range of service scenarios like new resident guidance and homebuyer property selection, providing them with a highly efficient and immersive information delivery experience.

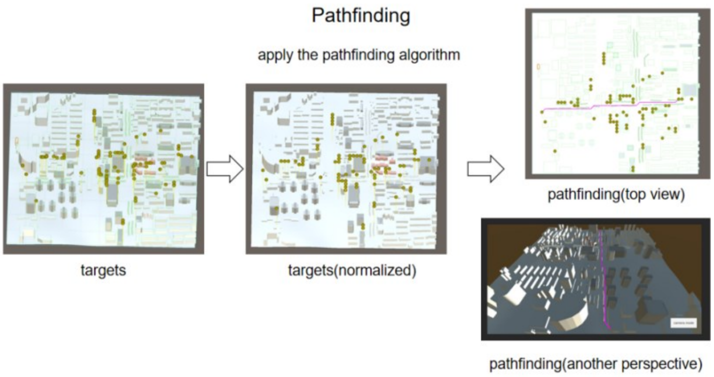

Figure 3. The final effect of path-finding

4. Evaluation and improvement

This study proposes an approach to fully leverage the serviceability, interactivity, and expansion of information categories of virtual reality technology in the field of urban visualization. It is aimed at the living scenarios of a wide range of community residents, which exhibit extensive service demands. However, significant deficiencies persist in terms of the accuracy of three-dimensional model precision and display performance within the system.

This project integrates geographic coordinates from Points of Interest (POI) data into a Geographic Information System (GIS) to align them with three-dimensional models, necessitating strict spatial data accuracy. High-precision data sources are crucial for the system's functionality and effectiveness in urban planning. Various sources like urban topographic maps, architectural drawings, and DEM/DOM data are used for three-dimensional modeling [10]. Different precision requirements dictate platform choices for large-scale and small-scale applications. In small-scale models (e.g., communities and neighborhoods), referencing the Virtools platform is essential for improving system display performance and ensuring fidelity to proprietary copyrights [11].

Moreover, this study needs testing and optimization, especially for user interaction with POI data in Unity. Establishing a digital community demonstration project is crucial for diverse research and improving display and service processes.

5. Conclusion

This paper introduces a "Virtual Reality-Based Community Life Route Guidance System." It utilizes Points of Interest (POI) data to create practical "life routes" encompassing four types of commercial hubs within a community and its surroundings. This system primarily aids new residents seeking guidance and home-buyers assessing convenience, offering interactive "economic life" experiences for residents. Its technological components include environment modeling, POI data processing, life path recognition, path visualization, and navigation. As discussed in the preceding section, the project mentioned in this paper presents significant opportunities for improvement in both model effectiveness and rendering techniques. Furthermore, there has been limited exploration of alternative application design and development scenarios for how urban visualization technology can better serve the lives of citizens. In terms of project optimization and evaluation, this paper has not yet employed methods such as surveys or interviews to investigate and enhance the practical application effects of the project. There is still room for improvement in this regard. Virtual reality is pivotal in digital urban planning, aligning with the rising interest in urban studies backed by remote sensing tech. Improved urban model accuracy from remote sensing sets the stage for various research and services. This study sheds light on the current state of interactivity and serviceability in virtual reality tech within urban planning.

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References

[1] LIU Yueling, Research on urban planning system based on 3D virtual reality technology[J], Modern Electronics Technique, 2020,43(19):182-186

[2] QIN Yuchu, Study on digital urban planning-oriented urban planning model[J], journal of ChongqingJianzhu University, 2006(04):138-141.

[3] LIU Zengliang, The Research and Practice of Applying Virtual Reality Technology to Urban Planning Management[J], Bulletin of Surveying and Mapping, 2010(05):45-47.

[4] Michelangelo Scorpio, Roberta Laffi, Virtual Reality for Smart Urban Lighting Design: Review, Applications and Opportunities, Energies 2020, 13, 3809

[5] David M. Simpson, Virtual Reality and Urban Simulation in Planning: A Literature Review and Topical Bibliography, CPL Bibliography, 2015

[6] The Construction guide of 15-minute radius livelihood service circles, China construction news, 2023

[7] Liang Xiaohui, Summary of Path Planning Algorithms[J], Value Engineering, 2020, 30(03): 295-299

[8] Huijuan Wang, Y. Yu, Quanbo Yuan, Application of Dijkstra algorithm in robot path-planning, 2011 Second International Conference on Mechanic Automation and Control Engineering

[9] Zhao Weiji, GONG Zhanyu, Wang Wen et al. Comparative analysis of several classical shortest path algorithms[J].Journal of Chifeng University(Natural Science Edition),2018,34(12):47-49

[10] Gu Chaolin, Duan Xuejun, Yu Taofang et al. The critical technology of digital city and its achievement[J], Digital City, 2002(01):16-20.

[11] José Paulo Guerra, MA, Miguel Moreira Pinto, PHD, Virtual Reality - Shows a New Vision For Tourism And Heritage, European Scientific Journal March 2015