Evaluation Method of Building Height Around Urban Architectural Heritage Based on Fuzzy Mathematics Theory

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Abstract. The height of urban buildings has a negative impact on the architectural heritage, making it gradually buried in high-rise buildings. By reviewing the height control and visual integrity assessment methods at home and abroad, this paper proposes a new building height control assessment method based on line-of-sight analysis and fuzzy mathematics theory. Taking Beijing Ming City Wall Relics Park and Hohhot Dazhao Temple as examples, the height control value of buildings around the site is calculated by line-of-sight analysis. The building height control value and the distance from the site are taken as two major factors, and the construction height of existing buildings and new buildings is evaluated by fuzzy mathematics theory.

Keywords: Urban architectural heritage, fuzzy mathematics, height control

1 Introduction

Urban architectural heritage contains rich aesthetic and historical values, but it faces the threat of being blocked by new high-rise buildings in the process of economic development and urbanization, which affects its visual integrity. For example, landmark architectural heritages such as Medan Emma Square and Cologne Cathedral have taken measures to reduce the height of the building or adjust the construction plan to protect its integrity[1]. People have gradually realized the importance of high-rise buildings that control the surrounding environment to protect architectural heritage. In this regard, there are some building height control methods at the level of urban planning at home and abroad to protect important buildings. Such as the British strategic overlooking measurement, French ' spindle ' overlooking control protection method. Japan shapes the characteristic coastal urban space through the landscape planning and control of mountain and sea view. Its planning methods include defining the scope of view, hierarchical division, building height management, landscape guidance and construction behavior control, as well as the implementation of the action plan[2]. In China, for example, Hong Kong limits the building height by formulating the legal document " Hong Kong Urban Design Guidelines. " Fuzhou proposes a comprehensive management and

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control strategy based on the mountain landscape overlooking control method to strengthen the protection of the corridor by legal and planning means[3]. In addition, some commonly used control methods include zoning control method, overlooking observation method combined with zoning control method [4], etc.

On the assessment of the impact of surrounding buildings, Janjira Sukwai et al. developed a visual sensitivity assessment tool by analyzing the relationship between Visible Mountain Areas and Visible Building Areas, to assess the visual integrity of mountain views in Chiang Mai, Thailand, and to identify visually sensitive areas that affect cultural landscapes[5]. Xixiao Bu et al. conducted a visual impact assessment of the Xi 'an Bell Tower and its surrounding new high-rise buildings. Through the design of simulation experiments, the height, top design and color of the building were adjusted to evaluate the visual perception of different groups of people[6].

The current building height control method only provides the best height value in theory, but in practical applications, we need a more flexible evaluation tool. This tool should be able to make a comprehensive assessment based on theoretical values when building new buildings or adjusting existing buildings. The assessment results will help support a diverse decision-making process, such as deciding whether to retain, lower the height or demolish certain buildings. In this way, we can promote the sustainable development of the city and the effective use of space while protecting the visual integrity and historical value of architectural heritage.

2 Method

This paper aims to study and propose an evaluation tool for the height of building construction around architectural heritage in urban space. The main methods are as shown in Figure 1, as follows: firstly, a three-dimensional model of the city is constructed, a building heritage is selected as the research object, and an observation viewpoint is set in an adjacent urban public space. Secondly, under the restriction of not completely shielding the architectural heritage and retaining part of the development space, the line-of-sight analysis combined with the three-point principle in aesthetics is used to construct the line of sight from the viewpoint to the 2 / 3 height of the architectural heritage as the best case of the height control value. Finally, using the fuzzy mathematics modeling analysis method, the membership function is constructed with the building control height and the distance between the building and the architectural heritage as the two major factors. The membership degree is calculated for different construction heights, and the decision-making is assisted by the analysis of the membership relationship.

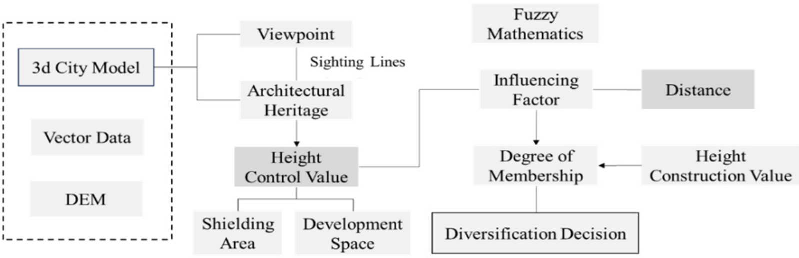

Fig. 1. technical route (Source: Author self-painted)

2.1 Urban Three-Dimensional Model

The city is the environmental space of the architectural heritage, and the buildings in the city are the main source of the impact on the architectural heritage. Therefore, three-dimensional modeling of the city to be studied as the basic data of the study. The city should have one or more architectural heritage as the object of visual impact protection. At the same time, it is necessary to select the appropriate viewpoint in the public space around the architectural heritage (such as parks, squares, viewing corridors, etc.) to ensure that the architectural heritage is within the scope of the viewpoint.

2.2 Analysis of Gaze

According to the subsequent evaluation requirements, two height control values are obtained by constructing the line of sight. The optimal height control value requires that the architectural heritage cannot be completely occluded, and there must be room for development. Therefore, the aesthetic three-point principle is adopted, and the line-of-sight analysis is used to construct the line of sight at the height of 2 / 3 of the architectural heritage from the viewpoint. In theory, the height of the building within the field of view is not allowed to exceed this line. The calculation method is shown in Figure 2:

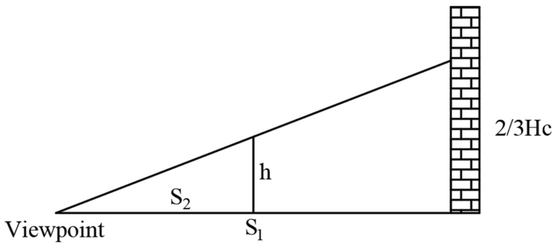

Fig. 2. Line of sight calculation method (Source: Author self-painted)

Among them, Hc is the height of the architectural heritage, h is the control height of a certain place, S1 is the distance from the viewpoint to the architectural heritage, and S2 is the distance from the control height to the architectural heritage, thus

$$h = Hc/S1 \cdot S2 \quad (1)$$

The limit height control value is the height control value based on the fact that the building just blocks the architectural heritage.

2.3 Fuzzy Comprehensive Evaluation

Through the theory of membership degree, fuzzy mathematics extends the membership relationship between elements and sets from traditional binary logic to a continuous metric, so that the degree of elements belonging to fuzzy sets can be quantified. The membership function maps the elements to the [0, 1] interval, where 0 represents non-membership and 1 represents full membership.

This study uses fuzzy mathematics to construct an evaluation system to evaluate the height of buildings around architectural heritage. The evaluation system takes into account the two main factors of building control height H and building and heritage distance D. For H, the worst case is that the building completely blocks the heritage (limit control height) and has no development space (H=0). Through the worst and best cases, the membership function U1 of H is constructed.

On the other hand, within the scope of view, it is required that the high-rise buildings should be as far away from the architectural heritage as possible, so as to weaken its adverse visual impact on the architectural heritage. Therefore, the membership function of distance D is constructed, and the membership degree is represented by U2 as shown in Figure 3.

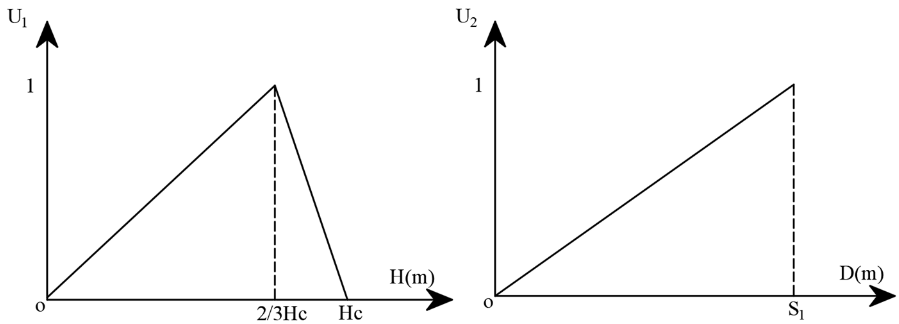

Fig. 3. Membership functions of H and D (Source: Author self-painted)

Secondly, the evaluation set B {appropriate, inappropriate} is constructed, and the membership degree of the appropriate degree of the two factors (height control value and distance) is calculated to form the comment matrix. To determine the weight of the factors, this paper sets the weight of the height control value to be 0.6, and the weight of the distance to be 0.4. Combined with the comment matrix and weight, the comprehensive membership degree is calculated. According to the value of the comprehensive membership degree, make a decision, as shown in Table 1:

Table 1. decision table (Source: Author self-painted)

Membership	<0.5	0.5~0.7	>0.7
decision	The height is not suitable and needs to be adjusted.	Need to analyze and make decisions after field research.	Highly suitable, no need to change.

3 Case Study

3.1 Case 1: Beijing Ming City Wall Relics Park

Research Area Status

The case study selected the Beijing Ming City Wall Relics Park, As shown in Figure 4. This section of the city wall was built during the Jiajing period of the Ming Dynasty and is located in the Dongcheng District. The total area is about 15.5 hectares, of which the city wall site and the southeast corner of the city cover an area of 3.3 hectares. The research selects the southeast corner building as the architectural heritage to be protected, and selects an intersection point in its southeast direction as the viewpoint.

Fig. 4. Beijing Ming City Wall Relics Park (Source: Author self-painted)

Results of Gaze Analysis

The view point is 1.123 km away from the southeast corner building and the height of the southeast corner building is 18 m (Note: the data used in the experiment are not completely consistent with the actual situation).

Fuzzy Comprehensive Evaluation

Evaluate a building with a construction height of 2 meters and a distance of 626.12 meters from the architectural heritage. The optimal height control value is 6.69 meters, and the limit height control value is 10.03 meters. The membership functions of H and D are constructed, as shown in Figure 5.

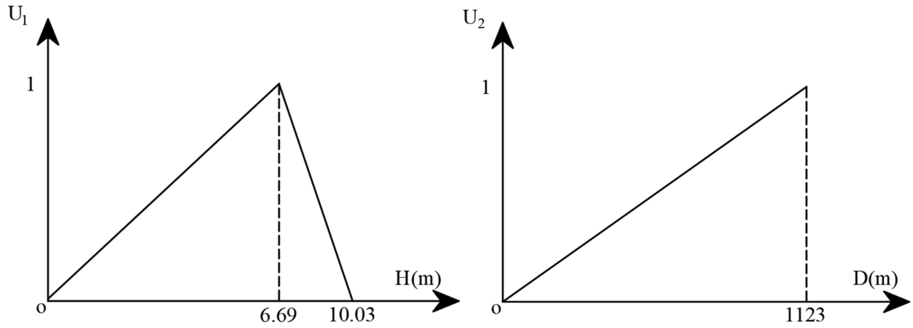

Fig. 5. The membership function of Case 1 (Source: Author self-painted)

Then the comment matrix is constructed: $\begin{bmatrix} 0.299 & 0.701 \\ 0.558 & 0.442 \end{bmatrix}$, and the result after multiplying the weight is $[0.403 \quad 0.597]$. The results show that the building can moderately increase the height and increase the development space.

Simulation Verification

As shown in Figure 6, in the three-dimensional model of the city, by simulating the existing urban environment, it can be seen that the building height is low, and the height can be increased appropriately, which is consistent with the evaluation results.

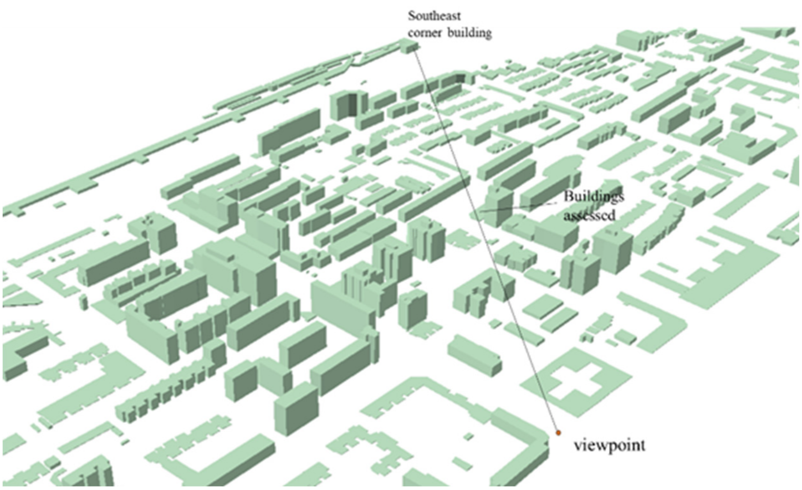

Fig. 6. Three-dimensional model of Ming city wall ruins park (Source: Author self-painted)

3.2 Case 2: Hohhot Dazhao Temple

Research Area Status

Dazhao Temple, located in Yuquan District, Hohhot City, Inner Mongolia Autonomous Region of China, is a Tibetan Buddhist temple with important historical and cultural values. It was built in the 6th year of Wanli (1578) of the Ming Dynasty and was co-chaired by Aletan Khan and his wife Sanniangzi. Now choose its northwest intersection as the viewpoint.

Results of Gaze Analysis

The viewpoint is 531.208 m from the north side of Dazhao Temple, and the height of Dazhao Temple is 18 m (Note: the data used in the experiment are not completely consistent with the actual situation).

Mathematical Statistical Results of the Model

Evaluate a building with a construction height of 6 meters and a distance of 263.97 meters from the architectural heritage. The optimal height control value is 5.96 meters, and the limit height control value is 8.94 meters. The membership functions of H and D are constructed, as shown in Figure 7.

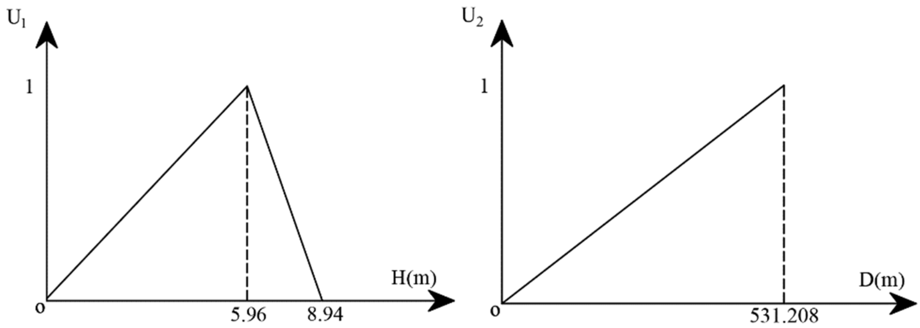

Fig. 7. The membership function of Case 2 (Source: Author self-painted)

Then, a comment matrix is constructed: $\begin{bmatrix} 0.987 & 0.013 \\ 0.497 & 0.503 \end{bmatrix}$, and the result after weighting is $[0.791 \quad 0.209]$. The results show that the construction height of the building should be appropriate and the status quo should be retained.

Simulation Verification

As shown in Figure 8, in the three-dimensional model of the city, by simulating the existing urban environment, it can be seen that the building height is suitable, which is consistent with the evaluation results.

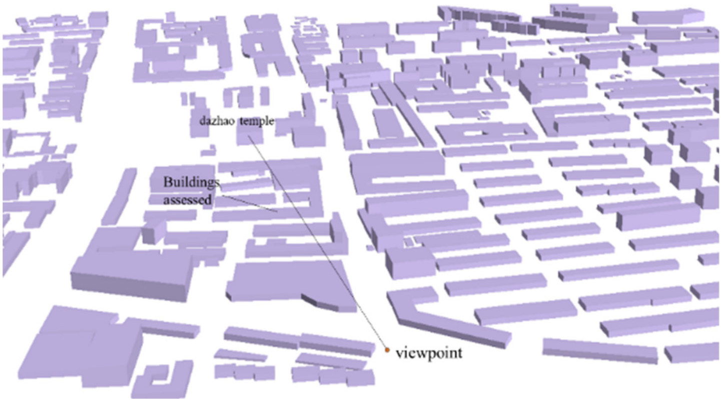

Fig. 8. Three-dimensional model of Dazhao Temple (Source: Author self-painted)

4 Conclusion

Based on the line-of-sight analysis method based on the three-point principle, this paper evaluates the building height at different locations. On the basis of protecting the visual integrity of architectural heritage, the three-point principle reserves the development space for the city. The distance factor determines that the height control of buildings close to architectural heritage is more stringent.

Urban planning policies in Europe and Japan usually focus on strict norms and clear design guidelines. Protect the urban landscape and skyline by setting specific height limits. In contrast, the evaluation method based on fuzzy mathematics theory proposed in this paper is more flexible and adaptable. In addition to evaluating the height, this research method also supports the addition of more influencing factors other than H and D (color, architectural style, etc.) to adapt to some special architectural heritage protection.

In addition, the combination of research methods and urban planning policies should be strengthened, and specific measures include:

- Strengthen the construction of laws and regulations, strengthen the construction of laws and regulations for the protection of urban architectural heritage, formulate evaluation norms, strictly define the protection objects, control areas, and influencing factors, and improve the relevant provisions for building demolition and additional floors.
- Strengthen the professional training of personnel.
- Continuous protection and public participation, for the control area of the building, to be regularly assessed. For buildings that need to change the height, follow up in real time to ensure the implementation of the policy. At the same time, accept public supervision, listen to the opinions of the masses, and further strengthen and improve relevant laws and regulations.

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