Research on 3D-Openness in urban area based on Urban Digital Elevation Model

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Abstract—**the external space is an important factor contributing to city construction. he openness is often used to measure the external spaces. The original openness models have some limitations such as that the view angles are confined to upward angles or the space under the viewpoint is ignored. This paper developed a new model based on the original 3D-openness model and index set of comprehensive quantification is established. The 3D-openness of main road is also extracted and analyzed. A typical block of 3D-openness parameters are discussed in different ways. The new model could be used in urban landscape design and city planning.**

1 INTRODUCTION

The form of external spaces of construction in urban area is closely related to the city physical environment and the city view environment. In cities, narrow streets and high buildings create deep canyons and this 3D external space plays an important role in natural ventilation and long-wave radioactive heat loss. Meanwhile, due to crowded buildings, vision is not open and people are increasingly in bad mood.

Therefore, the external space is an important factor contributing to city construction. Height-to-width ratio and frontal area index had been used to measure the geometry of external spaces. But external space is quite complex and these measures can hardly used in practice. The openness is often used to measure the external spaces. The openness models can divided into two-dimensional models and three-dimensional visual models. In two-dimensional models, the openness has been commonly used to describe the shadow impaction of visualization or sunshine from neighborhood buildings or terrains in urban area. In some other literature, it has been called sky view factor.

By definition in 2D model(Fig. 1), openness is the ratio of the radiation received by a planar surface to the radiation emitted by the entire hemispheric environment. There are two methods to calculate the openness. One is to project every building on the sky hemisphere and calculate the ratio of projection area to the entire hemispheric area, which is based on urban vector database. The other one is to utilize high resolution raster DEM to compute the openness using shadow casting algorithm. Unger had made a comprehensive literature review of this model.

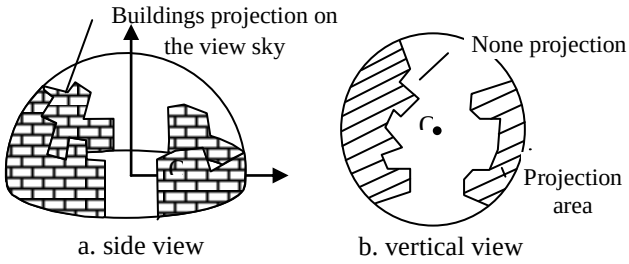

Figure 1. 2D-openness model

Another model presented is 3D-openness model(Fig. 2). It measures the volume of external space potentially seen from a given point .It can simulate the view space and express in terms of 3D visual spatial information.

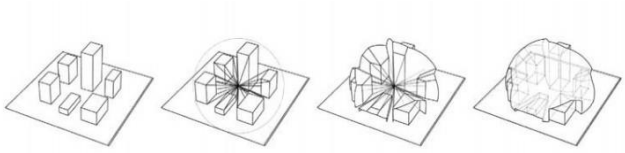

Figure 2. 3D-openness model (Fisher-Gewirtzman,2003)

In previous studies, the view point only in street level can be calculated but multi-level points also need to be discussed. Both models above can support a comparative evaluation of external space but there are still some limitations such as the view angel is confined to upward angles. The space under the view points at levels above streets are not taken into account. What's more, only

one index can hardly describe the external space. Hence, we developed the new model based on the original one, which overcomes the limitation and aims to perfect the theory of openness. The new model could be used in urban landscape design and city planning.

2 METHEOD: NEW 3D-OPENESS MODEL

Concept of new 3D-Openness model is given.

Analysis of the limitation of the original model, the 3D-Openness model is developed. The visual space simulates a sphere instead of a hemispheric(Fig. 3). The space under the view point is also taken into account. The new model is suitable for construction-intensive area.

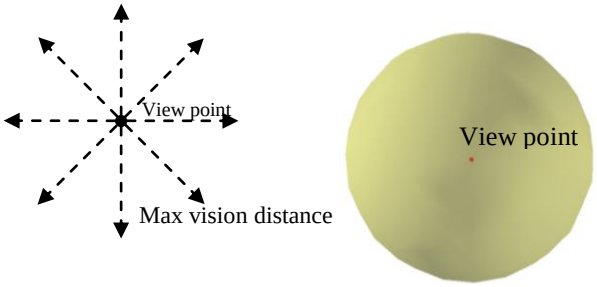

Figure 3. New 3D-Openness model

To give the external space an better description, visible space character are analyzed in detail , which can provide some basic rules for adopting quantified index. The index set of comprehensive quantification is established, considering four aspects of visible space hierarchy(Fig.4), visible space fluctuation(Fig.5), spatial extend direction(Fig. 6) and 3D visible volume.

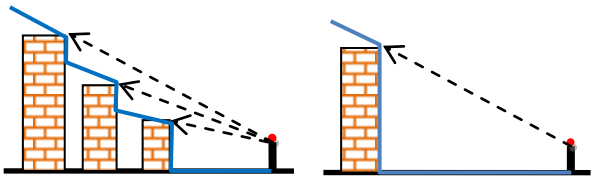

Figure 4. Different visible space hierarchy

Figure 5. Different visible space fluctuation

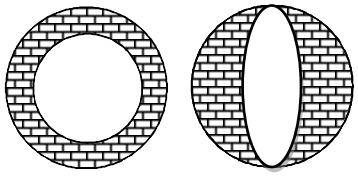

Figure 6. Different spatial extend direction

Among these indexes, the quantity of levels and Height Width Ratio(HWRatio) are about visible space hierarchy. Wave Frequency and Wave Range parameters are about visible space fluctuation, whose calculation methods based on the city skyline. Wave Frequency is defined for measuring the times of the visible space in one direction different from the next direction. Wave Range is defined for measuring the difference between the visible space in two direction. Shape Index, Skewness, Connectivity and Open Direction parameters are about visible space direction, whose calculation methods based on the 2D graphics which are derived from the 3D visible space projection. Shape Index is defined for measuring the complexity of visible space. Skewness is defined for measuring the even degree of visible space. Connectivity is used to describe the patency in one direction and the direction with highest patency is Open Direction. Visible Ratio is defined as the 3D visible volume divided by the volume of view sphere, which is used for measuring the percentage of the visible space that is filled up by the hypothetical spherical view area.

3 URBAN DEM AND STUDY AREA

Urban DEM (Digital elevation model) is widely used visualization analysis of urban landscape and analysis of terrain visibility, for it can properly express the 3-dimentsional structures of modern cities. Raster-based data model was used to analysis the openness in this paper.

Nanjing old town is taken as the study area, based on the established Urban DEM. Nanjing is the provincial capital of Jiangsu , and it is the economic , politics and culture center. It is still the comprehensive business center and the assembling place of service trade. Due to the fast development, Nanjing is changed greatly. A lot of tall buildings are built in a decade and population increases greatly. During the same time, some low buildings with great historical significance are preserved.

4 RESULTS AND DISCUSSION

The 3D-openness of main road is extracted and analyzed(Fig. 7). The result shows that Wave Frequency is trending downward while Wave Range is trending upward when the viewpoint is closer to city center. The open space on different side along the road are quite different. The size of open space goes up and down alternately.

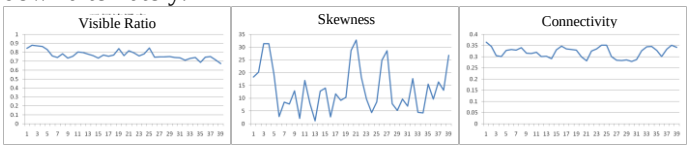

Figure 7. 3D-openness indexes of main road

A typical block of 3D-openness parameters are discussed

The result shows that more landscape levels could be involved in view sight in southwest areas of the block and north areas in Zheng He Park. The open space are larger in the corner and edge than in the other place in this block. The result shows that living on fifth floor or above could get more landscape levels and much larger space than other floors in this building.

The improved openness model has overcome the limitations of the original one and it can describe the open-space in different analysis angles. The new 3D-openness model have actual application value in the selection of sites and the design of houses.

5 ACKNOWLEDGMENT

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