

# APPLICATIONS OF 3D CITY MODELS BASED SPATIAL ANALYSIS TO URBAN DESIGN

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### ABSTRACT:

Urban design is a subject that is concerned with the shape, the surface and its physical arrangement of all kinds of urban elements. Although urban design is a practice process needs much detailed and multi-dimensional description, however the urban designer can only analyse urban space with script and imagination in the past, and only the urban design guideline and some drawing picture were carried out in the traditional design schema. How to improve the quality of urban space effectually and to express the design schema perfectly are the problems troubling the urban designer for a long time. The 3D city models based spatial analysis gives the possibility of solving these problems. Comparing with the traditional applications of 2D GIS in urban plan, the 3D city models based 3D spatial analysis would be more meaningful for the urban designer. The computable analysis models could be constructed under the urban design guideline. Through the integration of analytical models and realistic visualization models, the 3D spatial analysis that is impossible to the 2D GIS can be carried out.

Instead to be described with some adjective words, the designing schema and rules can be presented and analyzed in 3D virtual environment. The change of the urban fabric and the building density could be analyzed through the structure analysis. The noise environment, sunshine condition, heat environment, ventilation condition, and pollution condition could be analyzed through the physical quality analysis. The control of the height, the color and the style of the buildings, and the evaluations of the surrounding environment of the squares and the streets are also available based on the visual impact analysis. The analysis of the distribution of different function parts and its proper place are possible through function analysis of urban space.

Based on the 3D city models, urban designer can express the design concept clearly. With the analysis functions, it is also possible to control and improve the quality of urban space effectually. There would be a great progress when we design the urban space with an operational 3D analytical system, like Cyber City GIS.

## 1. INTRODUCTION

“The visualization is perhaps the most significant of all activities in the design process to have been affected by the development of digital technologies” (Batty M, 2000). How far can we go forwards on the way of the application in urban design? Whether just as a visualization means, or as a decision support tool, a kind of ideation platform? It is the problem that we have discussed for a long time. There is an agreement accepted by most of researcher that the computerized design generation is difficult because of the complex, the originality and the to-and-fro process of design. So most of the research efforts are concentrate on the space analysis and the decision support.

In this paper, urban space study based on the 3D city models (3DCM) is a kind of special application research. Urban design plays double roles in urban construct process: control and guide. To Control and evaluate the form process of urban space efficiently is the primary task of urban designer. The 3DCM is no doubt a powerful tool because of its characters for multi-dimension, visual, and multi-attribute. The objectives of this paper are three-fold: (1) provide an introduction to the meaning of 3D city models application; (2) set up a research framework for the content of application, give the answer for what we could do at all using the 3DCM in urban design field; (3) put

forward some new viewpoint for 3D city models based visual analysis.

In this paper, 3DCM is the spatial framework data body of Cyber City GIS (Zhu Q, Li D R, Zhang Y T, Hong D, 2002), and it is different from the 3D CAD models. 3DCM is not simply as an abstraction of various objects of cities. Besides the geometric characters, It also contain the geographic information and other attributes, for example, the location coordinate, the building height, color, texture and so on. Although the primal intention of most 3DCM is for visualization, what we want to do now is to go for on the way of its more valuable applications.

## 2. THE IMPORTANCE OF THE 3D SPATIAL ANALYSIS FOR URBAN DESIGN

### 2.1 The Present Development of Urban Design

Urban design is the holistic ideation and the arrangement for the urban form and the urban environment, and it run through the whole process of the urban planning. It is a subject mainly involving the shape and the surfaces of all kinds of urban elements, and its research focuses on the urban space formed by these elements. It has been defined by Barnett (1982) as "... the process of giving physical design direction to urban growth, conservation and change". In fact, there is not a universal definition for urban design, but we can see that the

enhancement of the space quality is the origin at the genesis and still be the kernel problem of urban design until now. There is another famous word of Barnett: Design the city, not design the building. "Unlike architecture where the concern is primarily with the construction, appearance, and internal organization of buildings, urban design relates physical arrangements of buildings and streets to functional organization which in turn reflects the social and economic structure which makes the built environment function or dysfunction." (Batty M, 2000)

In the history of urban design development, Camillo Sitte is the first researcher to insist upon the three-dimensional study of city form. In his famous work: *City Planning According to Artistic Principles*. He believed that the designers of cities must consider three-dimensional urban form. His work was influential in shifting the design of cities from engineers to architects. "Though planning was concerned with many things, the physical form of the city was a central concern" (Langendorf R, 1999). The urban designer take the urban space environment as the mainly design object.

In fact, all the effort of the architects and planner is to construct a pleased, comfort, and efficient space. People always think that they plan the city, design the physical form of the buildings, actually they use the space formed by the building entities, whether inside space or outside space. That is the reason why the urban designers take the urban space as their design object. Eliel Saarinen thinks that urban design is the art of 3D space organize (Saarinen E,1943). Now Urban design has no longer simply been taken as the organizational art of geometric space, the human life and the social meaning contained by the urban space has been recognized more and more, but as the media of the human city life, urban space is the major research object of urban designer all along from the beginning to now. The spatial analysis is very important for planner and designer, but there is no any efficient way to control and design the urban space until now.

## 2.2 The Existing Problem

Although urban design is a practice process needs much detailed and multi-dimensional description, however the urban designer can only analyze the urban space with script and imagination in the past, and only the urban design guideline and some drawing picture were carried out in the traditional design project. With the traditional design tools, we can only find the problems firstly, analyse the space with the sketch, put forward the scheme, visualize the design result through the 2D map or picture. How to improve the quality of urban space effectually and to express the design schema perfectly are the problems troubling the urban designer for a long time.

Urban designer and architects need to represent and communicate their viewpoint in a proper way. In the same way, urban manager want to control the urban space efficiently; the owner or the stakeholder of course want to communicate with the designer without any obstacle; for most of citizen, they look forward to know the plan or the design process and participate in it conveniently. All these also need a multi-dimensional environment, but the true 3D space or 4D space (to consider the dynamic change) can't be expressed and designed in 2D plane because of its multi-dimensional characteristics. That is the reason why the 2D GIS has been used in urban planning field for so long time while urban design hardly have any new application in this domain. For urban planner and the urban designer, the development of 3DCM just can make up the lack of traditional GIS.

Urban visualization is proved to be a valuable tool for designers and planners. The 3D city models based spatial analysis gives the possibility of solving these problems. Comparing with the traditional applications of 2D GIS in urban plan, the 3D city models based 3D spatial analysis would be more meaningful for the urban designer.

## 3. THE THEORETICAL FRAMEWORK OF THE APPLICATION OF 3D CITY MODELS

Instead to be described with some adjective words, the designing schema and rules can be presented and analysed in 3D virtual environment. There is three evaluate principles for the urban space quality: comfort, pleasant to the eye, and convenient. The range of urban space study is so great that it can be classified into three aspects based on the three principles mentioned above:

### 3.1 Physical Quality Analysis of Urban Space

The physical quality analysis decides the comfortable degree of the people's sense. The noise environment, sunlight condition, heat environment, ventilation condition, and pollution condition could be analyzed through the physical quality analysis.

In 2003, the HK news media reported that the reasons why the Taoda Garden residential area break out SARS, one of reason is the poor ventilation condition, especially the "wind curtain" between the tall buildings. It was discovered through the airflow dynamics analysis in computer by Pro. J.Y.Zhou of the Chinese University of Hong Kong (CHUK, 2003). This research suggests that the physical quality analysis of urban space may often have a social impact on the human life. The arrangement and properties of the buildings and the urban space around us could control our behaviour.

Based on the 3DCM, we can choose any date and get the sunlight time of any place on any building of a day (sunlight analysis), for example, the windowsill of the first floor. If the sunlight time below the set time, this building will be highlighted and show the lacking time. Especially, we can see the dynamic change of the building shadow in the range of time set, thus the sunlight condition can be evaluated in 4D environment as shown in Figure1.

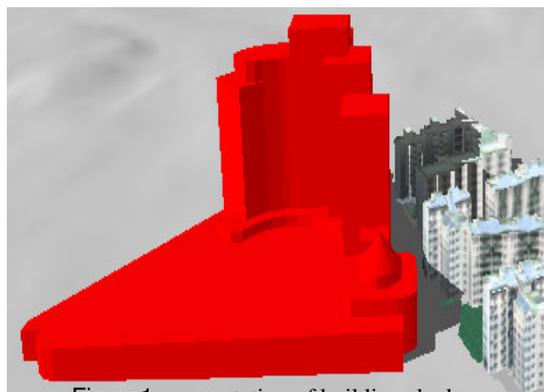


Figure1 computation of building shadow

Another potential application of 3D city models is the ventilation analysis. With the merge of more and more skyscraper, the ventilation problem appears. Minus pressure behind the windward of tall building is good for the inside ventilation, but for outside it would make people discomfort especially in cold winter. The more the tall building has, the more complex the airflow is. How to compute the airflow

activity and control its change accurately is a big problem for the architecture and the urban designer. With the 3D city models, we can construct the analytical models to simulate the airflow activity.

### 3.2 Visual Quality Analysis of Urban Space

The visual quality of urban space decide the pleasant degree of human's mind which evoked by the vision. In practice, urban design concerns with the physical arrangement of the basic component that makes up the built environment at the level of buildings, streets and landscape details. Therefore, visual thinking of space is necessary in the design process. At the same time, the designer should take the user feeling as the central point to analyse the location and the relationship of different urban element. Visual analysis is no doubt a powerful tool.

Through the virtual reality presentation of multi-dimensional urban models we can carry out the "true" visual analysis that is impossible to the traditional 2D GIS. The control of the height, the colour and the style of the buildings, the evaluations of the surrounding environment of the squares and the streets are also available based on the visual impact analysis.

### 3.3 Structure Analysis of Urban Space

The analysis of the distribution of different function parts and its proper place are possible through structure analysis of urban space. Besides of this, structure analysis can also control the change of the urban horizon contour and the building density. Optimize the urban space structure is the import content of urban morphology.

Spatial analysis is one of the key features that differentiates GIS from other forms of spatial information systems such as spatial-databases, computer cartography and computer aided design (CAD). "Space syntax models the spatial configurations of urban spaces by using a connectivity graph representation. Such a configuration of space identifies patterns that can be used to study urban structures and human behaviour. Over the past two decades, space syntax theory has provided important computational support for the development of spatial morphological studies, in particular for the analysis of urban systems" (Jiang B & Claramuntz C & Klarqvist B, 2000) .

In china, there are a lot of old cities like Lijiang of Southwestern China. They formed with the natural order in a long history. The urban space of it is full of life interest. Their urban structure has high research worth. To analysis its urban space structure can help us improve the space quality of present cities.

## 4. 3D CITY MODELS BASED VISUAL ANALYSIS AND PRESENTATION

For urban designer, the most significant application based on 3D city models is the visual analysis. In 3D dynamic virtual environment, through the visibility computation according to the simulation of human vision and the visual analysis for the visible field can make the design process more realistic and scientific.

### 4.1 Visual Analysis and The Visibility Computation

Visibility as a term---along with some related terms, such as viewshed, visual quality, and visualization is very much evident in the literature and practice of landscape planners and designers. The visible field with certain eye-level and view-angle can be computed, and it is the possible field we can see at

certain observe point. But what we can see does not equal to what we seen. What we see among what is visible may depend on the purpose and preconceptions (Stephen Ervin, Carl Steinitz, 2003) and depend on the weather, the colour and so on. Visibility computation is the premise of the visual analysis. Of course, the view field we seen is a subset of visible view-field. In order to present the visual impact properly for urban design, the visible field and the visual scene should be visualized, so that the user can extract the visual information themselves and implement the evaluation. Multi-mode and real-time dynamic presentation is a good choice.

### 4.2 Multi-mode and Real-time Dynamic Presentation

In 3D dynamic environment, people usually can not ascertain the right orientation because of the rich visual information. However the 2D map can present the real orientation efficiently, it is a powerful navigation tool in 3D dynamic environment.

At the same time, the computed visible view-field should be outstanding through the way of giving highlight or different colour to the surface of visible object. This is the way we present what we can see in 3D environment.

But how can we present what we have seen? The visual scene at special viewpoint, which could change the eye-level and the view-angle so that to fit different users, should also be supported. The different user can get what they seen through the custom-built visual scene.

The above description gives full presentation for the visual analysis environment, and these three presentation modes may be viewed in real-time through dynamic link. Here gives an example to this kind of presentation as Figure (2, 3, 4) which coexist in one interface. Only in this way the visual impact of urban space can be fully expressed. In order to implement the visual analysis effectively, the 3D city models should be editable, and the space attribute of the models like colour, texture and so on should be changeable.

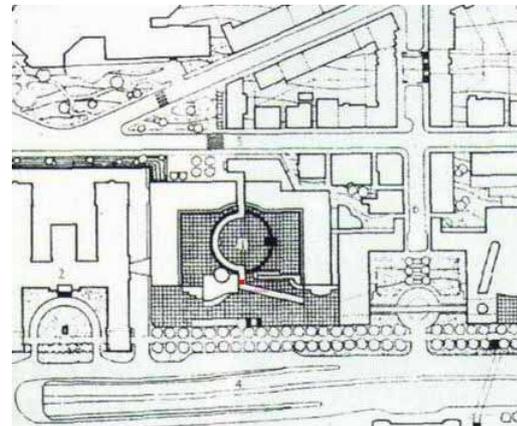


Figure 2 Stuttgart art gallery -plan  
(the red point shows the orientation of observe point)

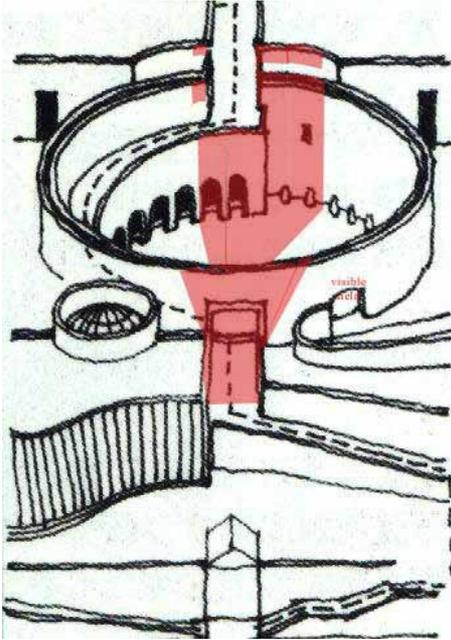


Figure 3 the visible field based on the visibility computation (the red-filled field shows what we can see)

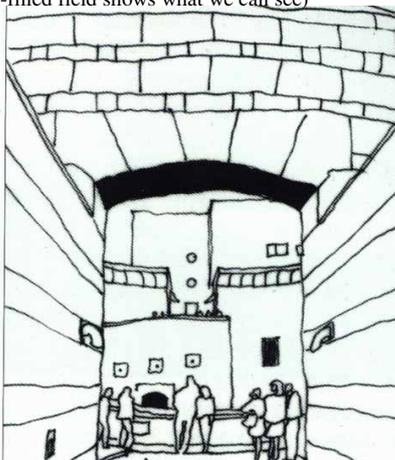


Figure 4 The visual scene in which we can get what we seen

### 4.3 Visual Spatial Analysis

The visual analysis concept model and the analysis criterion come from the urban design guideline. Based on the 3DCM, the designer can carry out the alternating design in it, and embed their scheme into the 3DCM. For example, in some cases, the building should be back off the road red-line for some distance, and have the height limitation. Then the urban designer can convey their design result with the form of 3D control models, and evaluate the visual effect through the visual analysis. Selection of appropriate building types also could be guided by querying the associated database under the urban design guidelines. In Seattle, the urban design guideline includes the concept map of height limitation as shown in Figure 5 (Jin G J, 2002). If we embed the quantify criteria of urban space like this in our analysis models, we can control the urban space more efficiently.

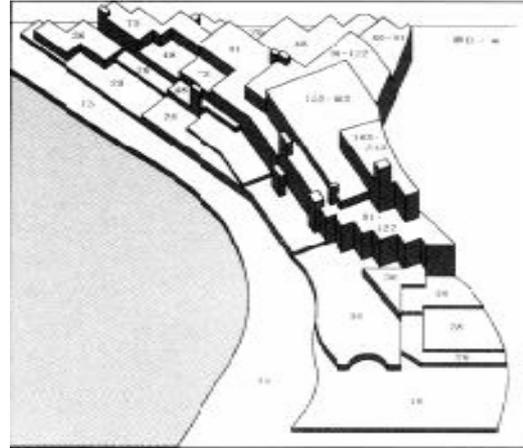


Figure5 the concept map of height control of downtown in Seattle (Jin G J, 2001)

Through the height limitation of impressible area, the back-off distance control of the street building, or the open space control, the designer can either give a fully presentation for the urban design result or give a effectively control and analysis for the visual quality of urban space.

“Enthusiasm for automated visibility analyses has grown significantly over the years because of marked improvements in hardware and software algorithms. The future advances in this field will eventually help solve the elusive visibility analyses in three-dimensional urban and natural environments” (Rana S, 2003).

## 5. CONCLUSION

A successful decision support system should be easy to operate. The design process is complex, and it involve in all the aspect mentioned above, the physical quality, the visual quality, and the function quality of space. Generally, there need several analysis functions to do one decision. In one Spatial Decision Support Systems (SDSS), in order to adapt the design process, all the necessary analysis functions should be integrated.

Computer-aided visualization can change the way we think and the way we work. For the architects and the planners, it can change the way of design. The ability to visualize potential modifications to the urban fabric and experience these changes in their actual context allows planners and designers to evaluate alternatives rapidly, in more detail, and for lower cost than through more traditional analysis. It also makes the results of planning process visible, allowing the public to view the proposed changes to their environment in a realistic fashion (Liggett R, 1997).

In moving from the abstract to the more concrete, 3DCM application may provide planners and designers with tools to better consider the three dimensional space in the design process, as well as better control the form process of urban space by the urban governor and allow of more people to participate in it. What we need is to build the urban space control system based on the 3DCM.

## 6. ACKNOWLEDGMENT

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