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# Application of Spatial Data Analysis in Architectural Planning

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**Abstract:** Relevant geographical conditions should be analyzed in architectural planning and design. GIS spatial analysis can analyze and display geographical data expediently. This paper explores the methods and approaches to apply ArcGIS, a popular GIS software, to architectural planning and design in combination with its spatial analysis function, so as to improve the efficiency and quality of planning.

## 1. Introduction

Buildings are the basic units that make up a residential community and also are the most basic material basis of human life. The relationship between people and land is becoming increasingly tense nowadays. How to improve the utilization efficiency of land, enhance the practicality and comfort of buildings and increase the coordination of the building complex is an important point to be considered in architectural planning.

Geographical environment factors should be considered and topography, topography, geological conditions and sunshine analyzed in architectural planning to finalize the optimum location and appropriate storeys, orientation and other building features and provide corresponding information support for architectural design. GIS technology can conveniently realize the collection, storage, analysis and visualization of information and has been applied in many aspects of architectural planning and design. For example, Guo Jia evaluated the vitality of urban space by GIS spatial analysis and thereby proposed the corresponding urban space planning method [1]; Zheng Yun et al. applied the combination of GIS technology and BIM to the visualization of construction supply chain, which can lower the operating cost of the supply chain and improve the competitiveness [2]; Wang Lingli et al. applied the spatial analysis function of GIS to urban architectural planning and design, which can improve the efficiency and effects of planning and design [3]; Liu Yinwen et al. analyzed the factors affecting the site selection for slope buildings and analyzed the method of site selection for slope buildings by GIS spatial analysis [4]; Tian Enming combined qualitative and quantitative methods and studied architectural colors with corresponding communities in Beijing as examples [5]; Zhang Shengchun designed and developed a building fire safety assessment system in combination with the features of building fire system and based on GIS technology [6].

ArcGIS is a most widely used GIS software both at home and abroad and has powerful spatial analysis function. This paper explored the application of this software in architectural planning on the basis of the comprehensive introduction of its spatial analysis function, so as to improve the efficiency and quality of planning.



## 2. GIS Spatial Analysis Function

### 2.1. Spatial Form

Spatial form is also called spatial shape and refers to the manifestation in space and the metric characteristics of extendible extent in different spatial directions of spatial objects. The spatial objects in GIS can be divided into points, lines, planes and bodies by their manifestation. Point objects have no morphological characteristics; the other three forms (lines, planes and bodies) have morphometric metric characteristics.

The length of line objects, the area and circumference of plane objects and other basic information in plane space can be calculated in ArcGIS. Such information can be used as the basic data in architectural planning and design. In three-dimensional (3D) space, ArcGIS can conveniently calculate the morphological parameters of a surface, including slope and aspect analysis, fill and excavation analysis and ridge line and valley line analysis. Such analysis tools can be used in such links of architectural planning as site selection analysis and project budget analysis.

### 2.2. Spatial Distribution

Spatial distribution describes the features of spatial variables and spatial objects in spatial combination, spatial arrangement and, mutual relations and other aspects from an overall and global perspective. Generally speaking, the objects studied in spatial distribution are called distributed objects mainly divided into point, line and plane objects; the spatial scope occupied by distributed objects is called distributed area which may be lines or planes.

In ArcGIS, the tools for measuring geographic distribution, density analysis, and multi-range clustering analysis are mainly used to deal with the distribution of point elements. Measuring geographic distribution includes median center, center element, average center, direction distribution and standard distance. Such tools can be used to analyze the distribution of buildings. The distribution of status elements is more about network state. ArcGIS has powerful network analysis function and can analyze geometric network data and network data sets. Such analysis tools can be used in the site selection analysis, building fire protection design and construction cost analysis in architectural planning. The analysis of plane element distribution can be converted to that of point element distribution.

### 2.3. Spatial Relationships

Spatial relationships are the relationship generated by the position, size, shape and other features of spatial objects. The most common spatial relationships are distance relationship, direction relationship and topological relationship. Spatial distance is a relationship describing the distance and closeness between spatial objects and has different definitions, such as Euclidean distance, Manhattan distance, grid distance and spherical distance. Spatial direction means a sequence of spatial objects in space, such as east, south, west and north. Topological relationship is a spatial relationship that remains unchanged under stretching and rotation, for example, “connect”, “separate”, “cross” and other predicates mean spatial relationships.

In ArcGIS, distance analysis, average nearest neighbor analysis, neighborhood analysis and cost distance analysis are distance-based analysis tools which can be used to deal with the problems in site selection analysis, building height control, building fire protection design and other aspects of architectural planning; the analysis tools based on topological relationships include the selection of spatial objects, extraction analysis and overlay analysis which can be used to process spatial data in architectural planning and can be used in correlation analysis. The number of analysis tools based on direction relationships in ArcGIS is small now.

### 2.4. Spatial Statistics

Spatial statistics is the statistics of the attribute data of spatial objects. Both quantity and position characteristics are taken into account in statistics. Spatial statistics is based on the law of relativity in traditional classical statistics and geography; and its purpose is to find out spatial relationships, spatial dependence, spatial autocorrelation and other spatial relationships between spatial objects and

corresponding statistical features.

The spatial statistics tools in ArcGIS include statistical analysis, exploratory spatial analysis, geostatistical analysis and spatial interpolation. Statistics analysis toolkit includes the classical statistical tools for attribute data and counting statistics, length and area calculating tools for overlapping and adjacent elements; exploratory spatial analysis toolkit includes the tools for spatial autocorrelation, spatial relationship modeling, hot spot analysis and high/low clustering. Such analysis tools can be used for the statistics of relevant attribute data, site selection analysis and spatial data processing in architectural planning.

### *2.5. 3D Analysis*

3D analysis is a spatial analysis method to obtain the slope, aspect, surface relief and other features of 3D spatial objects through the analysis of digital elevation model (DEM) data. The objects of 3D analysis are DEM which is a digital model representing the ground elevation with a set of ordered numerical arrays and includes regular grid model, TIN model and contour model.

ArcGIS has powerful 3D analysis and visualization functions and is equipped with special 3D analysis module. The analysis tools include the tools for 3D measurement, 3D path analysis, visibility analysis, slope and aspect analysis, skyline analysis, sunlight analysis and structure line analysis; besides, there are 3D visualization, 3D animation and 3D visualization tools ArcGlobe and ArcScene. Such analysis tools can be used for the site selection analysis, visibility analysis, sunlight analysis, skyline analysis and display of planning results in architectural planning.

## **3. Application of Spatial Analysis in Architectural Planning**

### *3.1. Analysis of Building Site Selection*

The analysis of building site selection should take landform elements, geological condition elements, traffic location elements, landscape elements, existing building elements and other elements into account. The landform elements mainly include elevation, slope and aspect. Buildings should be built on a site with gentle slope as far as possible. Meanwhile, aspect factors should be considered to facilitate daylighting and sheltering. In terms of geological conditions, buildings should not be built in places where geological hazards are likely to occur. The base geological structure should be considered, too. With regard to traffic, buildings should be built in places closer to various roads as far as possible to ensure convenient transportation. For landscape elements, sites with a wide view should be selected by sight line analysis. In addition, the distribution of existing buildings should be considered, especially in the site selection for public buildings which should be harmonious with the distribution of similar buildings. The data required include the DEM data, geological condition data, traffic network data and distribution map of completed buildings in relevant areas.

The specific analysis process with ArcGIS is as follows: First, the weight of each influencing factor  $W_i$  ( $i=1, 2, 3, 4, 5$ ) is determined by appropriate methods. Second, the data are preliminarily analyzed: DEM data are analyzed with the slope and aspect analysis tools in ArcGIS to generate the slope and aspect distribution map for the study area; the geological condition data are processed to obtain the distribution map for different geological types; buffer analysis tools are used for the buffer analysis of road network to obtain the distribution map for building site selection; density analysis or buffer analysis is conducted on existing buildings to determine the constructable area for buildings. Third, such distribution maps are reclassified so as to make the categories of the distribution maps consistent for convenient further analysis. Fourth, the grid calculator in grid analysis tools is used to calculate the distribution map for building site selection.

### *3.2. Sunlight Analysis*

Residential buildings should meet certain lighting conditions and meet certain specifications in the process of architectural design. Therefore, lighting analysis should be conducted during design. Lighting analysis refers to the analysis of the light conditions of buildings according to the motion of the earth and the sun and by calculating the correlation between solar elevation angle and azimuth angle. Generally, the results of sunlight analysis are evaluated by sunshine duration. The data required

for sunlight analysis include climatic zoning data for buildings, building location and height information and storey information. In addition, the corresponding design codes for buildings are also required for the evaluation of the results of sunlight analysis.

The process of sunlight analysis in ArcGIS is as follows: First, building vector data are converted to grid DEM data and reclassified. Second, aspect analysis tools are used to generate the aspect map for buildings and calculate the distribution map for backlight aspect. Third, the distribution map for backlight height is calculated and hillshade analyzed to obtain the corresponding analysis results. Fourth, the occlusion relation between buildings and shadows is analyzed to judge the sunshine duration of buildings. Fifth, whether the sunshine duration meets the codes is judged in accordance with relevant standards.

### *3.3. Skyline Analysis*

Building height should be controlled in urban architectural planning and design to ensure the harmony and aesthetics of urban skyline. Therefore, skyline analysis is required. The skyline is an overall visual structure formed by the top of the medium to high buildings in the city and an artificial urban landscape. The data required for skyline analysis include observation point data and the scene map for terrain.

The following three tools are available to skyline analysis in ArcGIS: skyline, skyline map and skyline barrier. Since skyline analysis tools cannot specify element elevation, elements should be converted to 3D ones before analysis. Observation point data can be realized by the element conversion tool in 3D analysis and building data by the data conversion tool in 3D analysis. Skyline analysis can be realized by imputing the converted 3D elements into the skyline analysis module. Skyline map analysis can calculate the visible area of the sky when people are located at a certain point in the architectural complex and generate the corresponding polar charts and tables to represent the corresponding horizontal and vertical angles of each turning point of the skyline. Skyline map analysis can be directly completed with analysis tools.

### *3.4. Building Fire Protection Design*

Building fire protection design is an important part of architectural design. Detailed planning and design are required for firewall distribution, the layout of fire doors and windows and fire shutter, fire extinguishing system and escape routes. The firewall distribution in planning should be determined by the area and function of buildings. The layout of fire doors and windows and fire extinguishing system should also be implemented in accordance with relevant regulation and in combination with the spatial features of buildings. Escape routes should be designed according to the features of internal road network of buildings. The data required for building fire protection design are internal 3D distribution map of buildings and the corresponding 3D road network map.

The corresponding distance can be measured with the 3D measuring tools in ArcGIS to determine the distribution of corresponding fire protection facilities; 3D route analysis tools may be used to calculate the features of interior roads of buildings so as to determine the optimal escape route; 3D visualization tools and 3D animation tools can assist in design and display the design results in a vivid manner.

## **4. Conclusion**

A lot of spatial and attribute data should be calculated and processed in the process of architectural planning and design. How to improve the efficiency and accuracy of analysis process is an important subject that we need to face. For this purpose, this paper explored the application of spatial analysis in architectural planning with ArcGIS, a commonly-used GIS software, as an example.

The meaning and function of ArcGIS spatial analysis were briefly elaborated according to its characteristics. On this basis, this paper explored the application of ArcGIS spatial analysis tools in the site selection analysis for buildings, sunlight analysis, skyline analysis and building fire protection design. Such application provides a new way to improve the efficiency and quality of architectural planning.

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