Evaluating Convex and Intersection Approaches of Graph Theory in Architectural Spatial Analysis

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Abstract

A method for spatial analysis in architecture and urban planning for more than three decades, which has been widely used in graph theory, is the method of analyzing convex space. In contrast, one of the methods of this theory, which is less used in architectural analysis, is the analysis of the intersection point. Although the intersection point method has several potential advantages to old methods in graph theory, there has not been a convincing comparison between this method and other methods.

An analysis of the convex space for each plan yields useful information for qualitative visual analysis. The visual analysis allows researchers to quickly identify the spatial structure of a plan and locate important functional spaces in relation to each other. For this purpose, a graph is usually drawn, that a single room or outer point is considered as the root of the graph. Such a graph is called the justified plan graph (JPG). A justified plan graph based on the type of spatial structure of the plan is divided into two sets, if the graph is deep, it is like a tree, if the graph is shallow, it is like a bush. Another common structure found in JPGs is the root-like spatial relationship, which is often seen in circular or looped plans. Root graphs have a very high flexibility or permeability in the building.

Convex space analysis requires simplification of the plan in the form of a set of convex spaces called in the graph as nodes. There are several procedures for this process, which are presented in three stages.

In the first stage, the rooms with four walls, the bedrooms or bathrooms, are defined as convex space. This is the first set of convex spaces that introduces spaces that there is no visual ambiguity in their convexity. According to the contract, convex spaces of a dimension smaller than $300 \text{ mm}$ are included in the largest contiguous space adjacent.

The second stage relates to non-convex spaces that are L-shaped or T-shaped. These rooms are divided in such a way that the least number of convex spaces with room function is created. If, after division, the spaces have not the primary function, they must divide so that the convex spaces produced have the lowest ratio of the perimeter to the area. According to Hiller and Hanson's view, convex space contains the smallest and fattest space. These kind of spaces are more circular and therefore have less ratio of the perimeter to the area.

In the final stage, the division of other spaces that are not convex is done according to the previous step.

After these steps, the convex map is ready to enter the Depthmap software. In this software, convex space tools are used to draw spaces and create graph nodes. Then the linking tool is used to add graph edges. The Depthmap software calculates the dimension of the graph theory for use in future analyzes.

Although the speed of the convex map production process is a significant advantage for some studies, it may not accurately analyze the location of a more precise points of the plan. For this purpose, an alternative process is needed to summarize the plan and convert it into a graph. This method, called visibility graph, is applied to a grid that is placed on the plan so that each square of the grid represents a node of the graph.

Graph edges connect both squares that are able to see each other. Thus, a straight line from the center of each square of the network is drawn to the center of each other visible square. This method is also an efficient method, but only when computer software is used. A kind of interaction between these two techniques - the visibility and convex space - is seen in another rarely used method. This method is called intersection analysis method in a axial map.

The process used in this paper to produce axial maps is a protocol for linking multiple classes in which the axial lines are defined as the lines of movement instead of the lines of vision. In this way, a line may begin from a point in a floor, move horizontally down the floor, and then go to the end of the floor, without passing through the stairs, but there is not necessarily a visual connection between the two ends of the lines.

The first stage of the production of the intersection map begins with the identification of the points where the two main lines are interrupted and marked on the map with a circle. Then the file containing the axial map and the intersection points is ready to enter the software. The Depthmap software does not have a preset tool
for analyzing intersection points. Therefore, using the convex space tool, each intersection point is considered as a node of the graph as a convex space, and it is manually connected to all points. Each node must be connected with at least two lines and connected directly to each node on which two lines are located. After adding all the connections, the software will be able to calculate the theoretical dimensions of the graph.

The "endpoint" method is a kind of intersection point method that examines the end of each axial lines. To do this, a straight line from the end of each line should be drawn to all the planar visible vertexes. If all of these vertexes are visible from intersection points, the end of the line does not have a unique surveillance feature and is considered an invalid location for the endpoint. Otherwise, the two ends of the axial lines become nodes in the intersection of the graph. For these endpoints, a new node in the software is mapped. After adding all the connections, the software is able to perform the relevant calculations.

In this research, three samples of Kashan’s houses are analyzed with convex space analysis method and their results are compared with the analysis of the intersection point. For each of these three houses, first, the convex space analysis is done and the mathematical results are calculated. When map is converted to graph, For mathematical analysis of the relationship between intersections, the paths in the original axial map are reversed. During the inversion process, two intersection point graphs can be generated, one that is entirely focused on the position of the intersection points (called the intersection point graph), and the other contains stubs with unique surveillance features (A type of intersection point graph that is called the end node graph).

From these two graphs, the intersection point of mathematical values is extracted which can be compared with the results of the convex space analysis. Through these processes, the weaknesses and relative strengths of these three methods are determined for the first time.

The result shows that the intersection point method is more effective in identifying the concept of space from the perspective of movement and routing than the convex space method, and also the inclusion or non-inclusion of stubs have a tangible effect on the integration values. Finally, it can be said that the present research, while mainly applying and evaluating the two methods of graph theory analysis, briefly describes examples of the valuable traditional architecture of Kashan.