APPLICATION OF SPACE SYNTAX FOR PARTITION SEQUENCING OF WORKING SPACE IN BUILDING CONSTRUCTION

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Abstract

Working spaces in the construction site are much more complicated than completed spaces in the building. There are many researches focus on partition of building spaces. However, few discussed partition sequencing in building construction sites. Space syntax is a set of techniques for analyzing spatial configurations. It has become a useful tool in a variety of researches. Partition sequencing of working spaces should be related to the working direction. However, with convex space and axial line, the partition sequencing became unrelated to the working direction. When critical space is blocked, the partition sequencing with axial line will be changed. It is significant to reveal the impact of the entire spatial structure when some of the working spaces are blocked. This paper discussed the improved partition sequencing theory and highlighted the importance of critical space and analyzed the spatial structure of working space. A real case project was demonstrated in this paper.

Keywords: space, syntax, partition, sequencing, working, conflict, building, construction

1. Introduction

Working spaces in the construction site are much more complicated than completed spaces in the building. Although, there are many researches focus on partition of building and urban road system, there was few discussing partition sequencing in building construction sites. A detailed description of the working space partition sequencing process in building construction will be demonstrated in this paper.

2. Basic definitions of graph theory

Graph theory is a branch of mathematics concerned about how networks can be encoded and their properties measured. In transport geography most networks have an obvious spatial foundation, namely road, transit and rail networks, which tend to be defined more by their links than by their nodes. A graph of a building can also be represented as a network, while its spatial expression can be easy to represent. It is shown in Fig.1.

A simple graph can be thought of as a G= (V, E), where V are disjoint finite sets of vertices, nodes and points and E are disjoint finite sets of edges, arc and lines. We call V the vertex set and E the edge set of G.

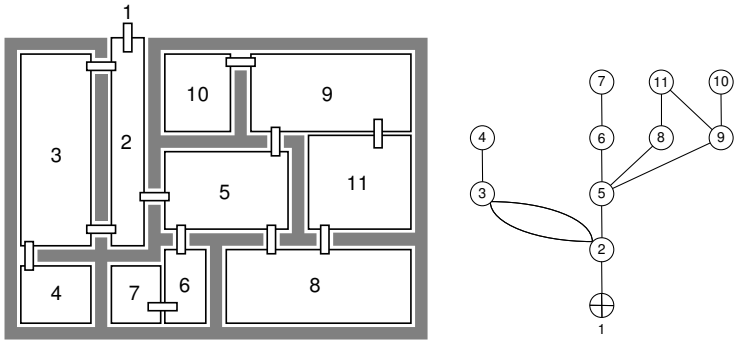
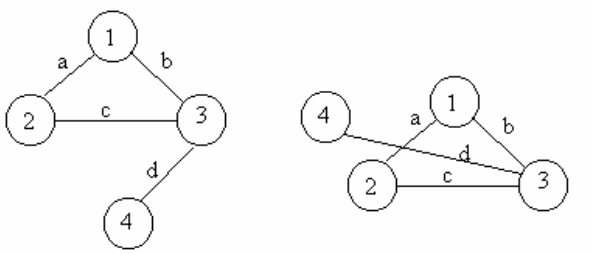


Figure 1: A graph of a building

Although the graphs sometimes seem different, it is actually the same graph when the amount of points and the distribution of the lines are identical. It is shown in Fig. 2.



(a) (b)

Figure 2: Two identical graphs

3. Space syntax analysis

The term space syntax encompasses a set of theories and techniques for the analysis of spatial configurations. Originally it was conceived by Bill Hillier, Julienne Hanson and colleagues at The Bartlett, University College London in the late 1970s to early 1980s as a tool to help architects simulate the likely social effects of their designs. This tool has become an application tool in a variety of research and practice around the world. It has been extensively applied in the fields of architecture, urban design, planning, transportation and interior design.

The general idea is that spaces can partitioned and analyzed as networks, and then represented as graphs that reflect the connectivity of all partitioned spaces. Over the past decade, space syntax techniques have also been used for research in fields as diverse as archaeology, information technology, urban and human geography, and anthropology. [1] It can be reflected in the following steps in Table 1.

Table 1: Steps of space syntax analysis

Partition sequencing of spatial structure	The spatial structure can be partitioned with convex space and axial line. Convex space is a Convex Polygon. A concave polygon must be transferred into the minimum convex polygons. In the convex space, every member can be seen by one another to satisfy the interaction function. The axial line is the longest straight line which chains convex polygons. Axial lines are based on the notion of visibility. They are named convex break-up and axial maps respectively. Convex break-up is composed of the minimum convex polygon spaces.
Justified graphs of spatial structure	After the partition, the spatial structure can be transferred into graph. The graph of the spatial structure represents permeable connections of all convex spaces and axial lines. In this graph, a joint stands for a convex space, and lines represent the connections among spaces. Any of these two elements can be based to explore the relative depths among the others. Draw all the depths into graph. Thus, the graph can reflect the structure of space. The space based to explore the relative depths called root space. In a tree-shape graph, most spaces are far from the root and the mean value of relative depths is larger. This graph can be called deep structure graph. Oppositely, a bush-shape graph can be called swallow structure graph.
Quantitative analysis of spatial structure	In terms of how each space and line intersects, various morphological parameters can be derived for the analysis of an spatial structure. These parameters include the integration value (Rn), control value (Cv), and connectivity index (CN). Integration value is derived from the concept of relative depth. Integration value is calculated from the mean of respectively minimum relative depth from the root space, so integrated value can be viewed as a comparative level of convince. The control value shows the degree to which each axial line controls its immediate neighbourhoods.

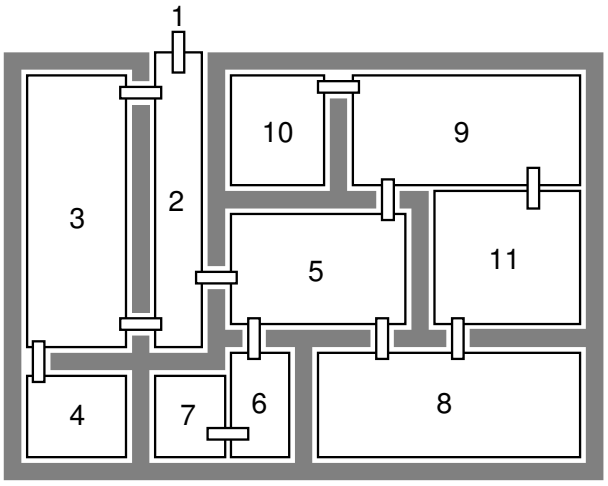


Figure 3: Convex break-up

Convex break-up disclosed the minimum links between convex polygon spaces, shown in Fig.3. Axial map described minimum links between connected lines, shown in Fig.4.

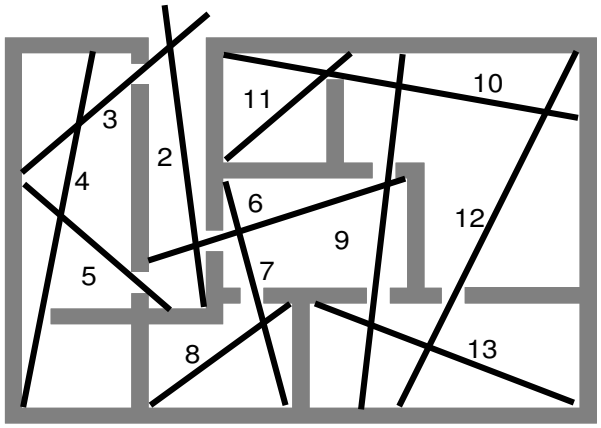


Figure 4: Map with axial line

In Fig. 5, 6 and 7, the different root-based graphs are shown as following. The space 5 can be recognized in a convenient position, because the root-based graph reflects swallow structure. Contrary to space 5, the root-based graphs of space1 and 10 reflect deep structure.

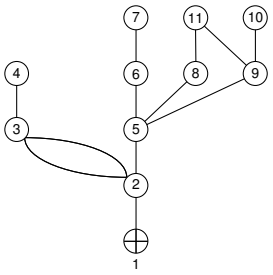


Figure 5: Graph of 1

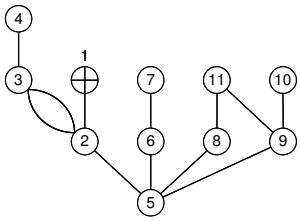
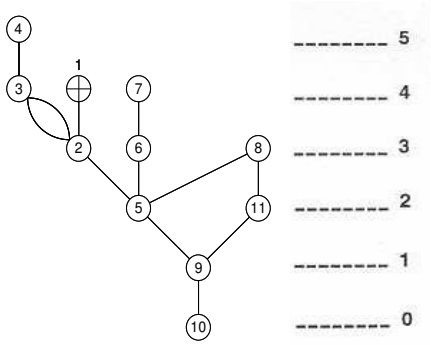


Figure 6: Graph of 5



Figures 7: Graph of 10

4. Partition sequencing problem in building construction

The partition sequencing with convex space and axial line is unrelated to the working direction, and there is no difference when you go either of the both working directions. However, in the construction site, working spaces are always related to direction, especially only one entrance or exit. It is obviously shown in Figure 7 when it comes to space 5's control value. Compared to space 9's control value 1.75, space 5's value 1.66 is lower than that. When space 5 is blocked, there are another six points (convex space or axial line) blocked but when space 9 is blocked, there is just one. Thus, in the construction site, it is necessary to take directional character into consideration. An improved partition sequencing method will be introduced next.

5. The improved partition sequencing in building construction

Spaces in the construction site are much more complicated than completed spaces in the building. [3] Thus, spaces in the construction site can not follow the partition sequencing of the completed building space which will be partitioned with convex space and then with axial line.

However, spaces in the construction site can only be partitioned with axial line in the past. That is because axial line is derived form the viewpoints of visibility and permeability, and both are come form mankind nature. Axial line map is represented as the least amount of longest visional lines connecting with different spaces. From above, it is safe to say that it is necessary to mix the directional character into axial line partition sequencing for spaces in construction site.

5.1 Partition sequencing for construction working spaces

Kunigahalli(1995)[4]extracted partition sequencing relationship form CAD model. Here are the steps:

1. Mark Boundary and Mark Obstacles. All obstacles section can be seemed as rectangular partitioning.
2. Mark all beam and beam intersection points.
3. Partition the interior space into rectangular partitioning sections.

This partition sequencing method, shown in Fig.8 and Fig.9, through intersection points and obstacles section is efficient to partition the construction site working space. However, lacking of consideration of spatial structure of the construction site and considering an individual working space won't be exactly partitioned by beams; it will not be all the real case. Thus, an improved partition sequencing method combined with spatial structure character and directional character will be discussed.

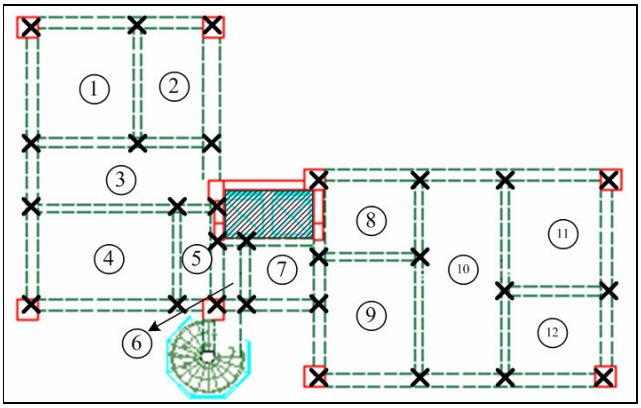


Figure 8: A case partitioned by method form Kunigahalli

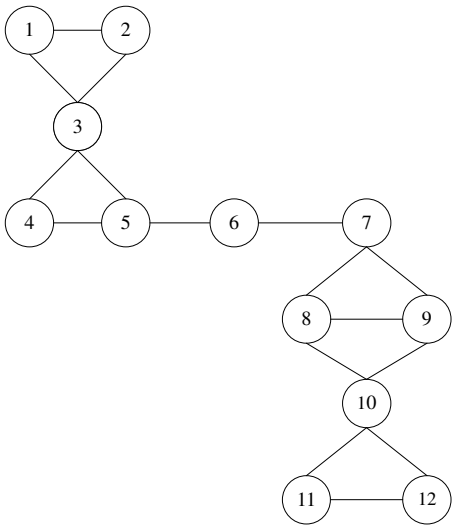


Figure 9: Corresponding graph for Figure 8

5.2 Partition sequencing theories in building construction

In order to express the directional character of spatial structure, it is significant to reveal the impact of the entire spatial structure when one of the axial lines is blocked. The partition sequencing theories combined with axial line and convex space are formed to overcome it.

Theory 1:
The same spatial structure partitioned with convex space and axial line is shown in Fig.10 and Fig.11. Firstly, form the graph in Fig.10 partitioned with convex space, it is obviously seen that when convex space 2 blocked, so did convex space 3. However, form the graph in Fig.11 partitioned with axial line, it is obviously seen that when axial line 4 blocked, axial line 5 still can connected with axial line 3. The partition sequencing with axial line shown in the Fig 11 apparently can not reflect the real situation of the construction site.

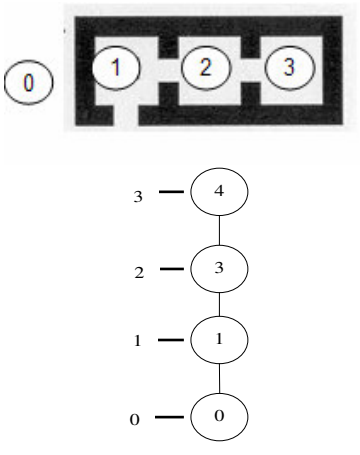
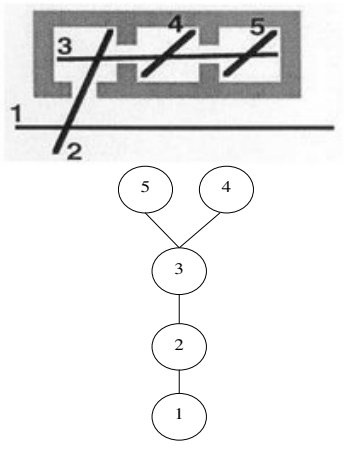


Figure 10: Graph with convex space



Figures 11: Graph with axial line

With theory 1, the spatial structure with axial line can not totally reflect the impact when some axial lines are blocked but the spatial structure with convex space can. Based on the identical results for axial line and convex space in building space, the partition sequencing theory should work with not only axial line but also with convex space.

Theory 2:
There is the assumption: Axial line A and B are represented as two of the longest axial line in a specific area. Through the quantitative analysis of spatial structure, the integration values of axial line A and axial line B are different. It has two possible detailed partition sequences for this specific area as shown in Fig.13 and Fig.14. If integration values of axial line B is higher than A, the detailed partition sequences as shown in Fig.13 should be chosen. On the other hand, if integration value of axial line A is higher than B, the detailed partition sequences as shown in Fig.14 should be chosen. In the theory 2, the longest axial line can be transferred into more specific convex space area.

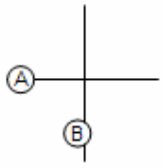


Figure 12

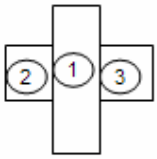


Figure 13

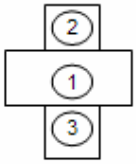


Figure 14

The different partition sequence can highlight the importance of critical space. Thus, the partition sequences should vary with different situation in real case.

Theory 3:
There is the assumption: Convex space 4 connects with a convex space that is not partitioned yet. It has two possible detailed partition sequences for this specific area as shown in Fig.16 and Fig.17 The difference of these two partition sequences is that in Fig.17 it highlights the impact to convex space 2 and 3 form convex space 1.

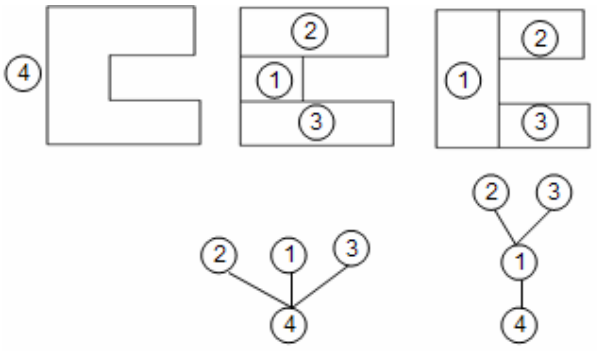


Figure 15 Figure 16 Figure 17

5.3 Partition sequencing process

The processing stage consists of two steps. The first step, mark boundary and obstacles and then partitioned the building construction site with axial line. Quantitative analysis of

spatial structure would be calculated. The second step of space sequencing would be using the theories mentioned above to transfer the axial map into convex break-up. The improved partition sequence combined axial line and convex space can highlight the importance of critical space.

6. Demonstrated case

The demonstrated case, Zhongshan Junior High School station, is one of the stations constructing in Neihu line of Metro transport system in Taipei. The station consists of three floors constructing including B2F, B1F and 1F layer. The first step of space sequencing would partition working spaces of the Zhongshan Junior High School station site with axial line. The axial map of the working spaces of B2F is shown in Fig20 and the whole graph of Zhongshan Junior High School station shown in Fig.18.

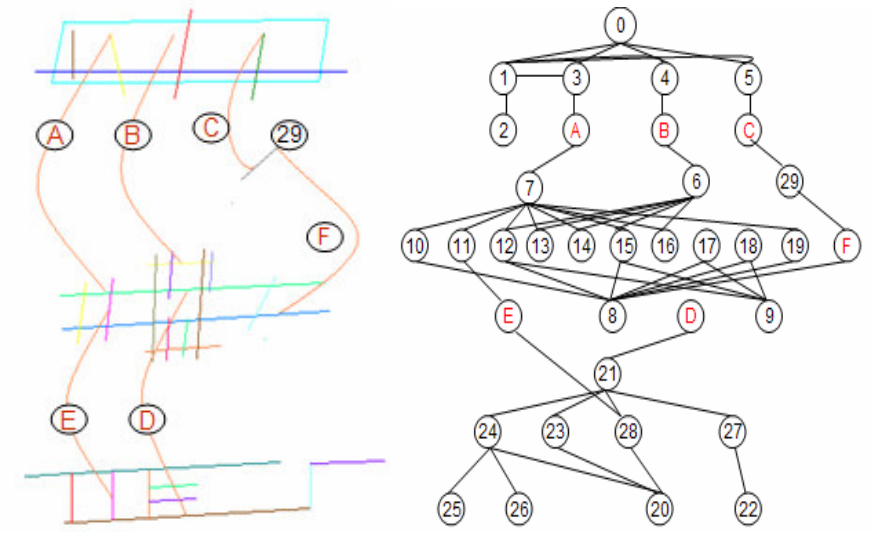


Figure 18: Graph of demonstrated case

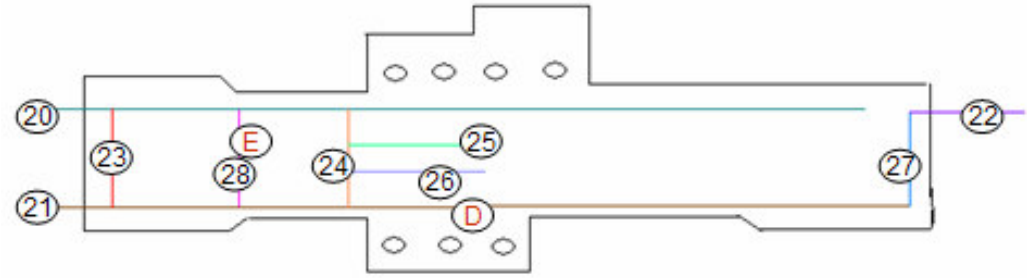


Figure 19: Map with axial lines of B2 Floor

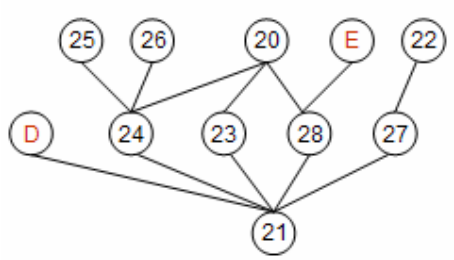


Figure 20: Graph of B2 Floor with axial line

The Second process of space sequencing would be using the theories mentioned above to transfer the axial map into convex break-up. Also, the RN and CV values would be calculated and the result is sequenced in Table 2. Then, by the theory 2, the graph of working spaces of B2F would be transferred as Fig 22. The improved partition sequencing discussed in this case highlights the critical spaces of the construction sites.

Table 2: RN, CV and CN values of the graph in Figure 18

Order	Rn	CV	CN	End
1	7	7	7	N
2	14	8	8	N
3	12	24	6	Y
4	15	6	1	N
5	11	1	21	Y
6	6	21	9	N
7	13	9	0	N
8	16	0	12	N
9	8	27	15	Y
10	10	20	24	N
11	19	29	-	N

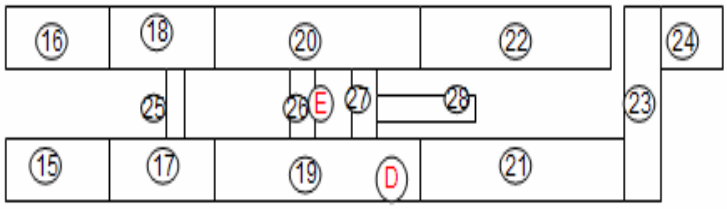


Figure 21: Convex break-up of B2 Floor with partition sequencing theories

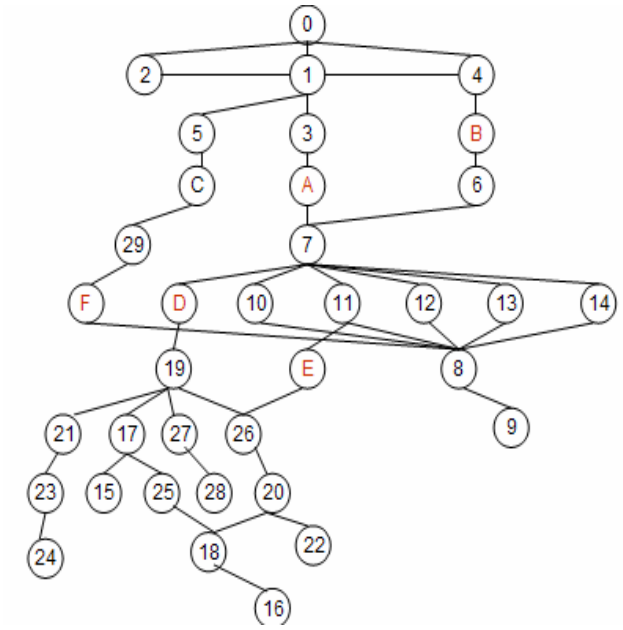


Figure 22: Graph with partition sequencing theories

7. Conclusion

Traditionally the working spaces only can be partitioned with axial line. However, the spatial structure with axial line can not exactly reflect the overall impact when some axial lines are blocked. However, spatial structure with convex space can solve this problem. In order to clearly reflect the impacts of blocked axial lines, the improved partition sequencing theories discussed in this paper highlighted the importance of critical space. The proposed theories which combined axial line and convex space for partition sequencing of working spaces have been demonstrated in this paper.

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