Space syntax analysis – methodology of understanding the space

Weronika DETTLAFF

Keywords: Space Syntax; way finding; spatial configuration; individual; spatial decision making

Abstract: Nowadays space is considered to be a net of connections between different areas. The questions how to delineate its character and how it is possible to objectively compare two spaces is a matter under consideration. This was the reason for creating new theories about the structure of space. Space syntax analysis (SSA) or simply Space Syntax defines a number of theories and research areas devoted to the analysis of space configuration. Ongoing research and observations of the configuration of spatial settlements and human behavior within in the past years has shown a close relationship between the physical structure of space and the quality of life of its inhabitants. SSA is used as an academic and commercial tool to analyze projects on an urban and building scale. It is a tool of sustainable development used to study movement of space users, crime in the city, anti-social behavior, economics and viability of service, transport or health behavior.

1. The origin of space syntax analysis

The first studies on the fundamental method of space syntax analysis were made in Bartlett School of architecture at University College London in the 80s. An introduction to the analytical method was presented in an article in Environment and Planning (Hillier et al., 1976). Its authors created a morphological language trying to describe the basic elements of space using some special characters. Their main goal was to isolate the minimum settlements, the basic syntax of space and describe relationships and syntactic rules that are limited by various barriers. The authors set themselves the task to offer syntax patterns of space. They went from the assumption that the greater problem is to describe the existing structures and not their creation. Thanks to the derived formulas and indicators some basic types of space syntax could be structured and described. The ending chapter of their paper which was devoted to the relationship between the place and the community became the starting point for the development of space syntax methodology (Hillier et al., 1976). A landmark

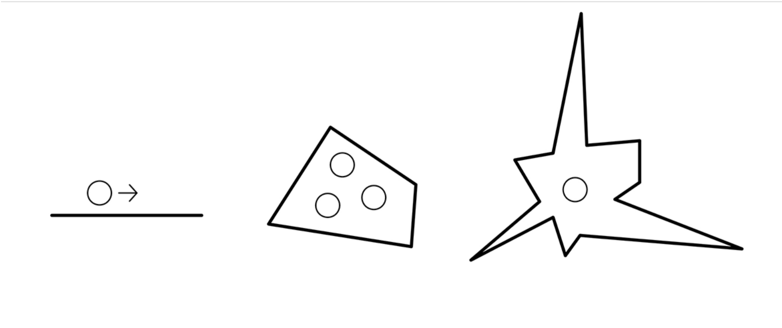

Fig. 1. Figure taken from (Hillier and Vaughan, 2007). It presents: (a) representation of the way people move, mostly along a line; (b) convex space where users see each other and in which interactions take place; (c) the visibility filed (isovist), which has a different shape depending on where the observer is located.

book *The Social Logic of Space* was published in 1984. It deals with the theory of the impact of spatial configuration on the social life and vice versa (Hillier and Hanson, 1984).

From its beginnings the method was used as a tool to help architects to simulate the likely effects of their social projects. Since then the methodology has been developed as a design method, which can determine the nature of space, help to understand how buildings, areas, and even entire cities operate. The most important factor in the SSA remains space configuration, and relations that occur in it. The theory proves that the way in which elements are brought together affects the behavior of its users (Hillier, 1996). The theory is based on several principles described mathematically, which gives a possibility to generate graphs and numerical results, map and analyze linear space availability (*spacesyntax.com*, 2014).

2. The basics of the space syntax method

The whole theory of space syntax is based on the rejection of the metric properties of space. Instead, spatial configuration is represented by topological data. Intrinsic properties are shown on topological graphs. Representation of the relationships between the elements becomes the fundamental subject of spatial analyzes, where an urban grid is used to examine social use of a space (Emo et al., 2012).

In their book, (Hillier and Hanson, 1984) describe a method of linear and nodal description of space. The first method consists of analyzing the axial maps – linear maps, based on observations of visibility. The starting point is the deliberation about people's behavior, and their perception of space. Fig. 1 presented below is a simple representation of three different ways how people perceive space.

These are the three ways of representing space which show the same thing from different perspectives. The first representation is mostly used in axial maps to analyze urban systems. The second one is the best one to analyze rooms, and other closed structures. *Isovist* encompasses the area that can be seen or perceived by a particular

Fig. 2. Diagram taken from the lecture (*Spatial Accessibility & Human Behaviour - Designing places for People, Space Syntax - Christchurch*, 2013).

user from a particular point in space. It is mostly used to show different perspectives in squares and open public spaces. In this paper most analyses use axial maps. The topic of isovist changes and the term itself have been widely described in (Benedikt, 1979). The type of analysis depends on the selection of the space representation. It is possible to run an analysis of an axial map, a convex map, a convex space, or analyze changes of the isovist fields.

The theory of space syntax tries to explain non-discursive properties of space by showing the way how elements should be connected to know what the users see. A simple example can be used to show why the SSA method does not use metric representation. The movement of users is divided into free and defined (for a specific purpose). While considering the defined movement of people, it can be seen that not all pedestrians wanting to get from point A to point B will choose the shortest path in terms of its metric. A lot of them will choose the simplest way, the shortest topologically, which will allow them to move with the smallest possible number of changes of direction. The phenomenon is illustrated in Fig. 2.

The thinnest line represents the connection from point A to point B, the line of the medium thickness is the shortest way measured metrically, and the thickest line shows the shortest way topologically.

Observing people can be enough to determine whether a space functions correctly or incorrectly in relation to its purpose. This may involve following pedestrians around the city, tracking their movements and drawing lines of their movements. The movement of most people appears to be consistent, repeatable, and therefore foreseeable. Through observation it is possible to visualize the results as maps, diagrams and graphs. Usually in visualizations of traffic different colors are used for places with different frequentation of movement – from warm red (most frequented) through orange, yellow and green to the coldest blue (less frequented). It is recommended to carry out similar observations for both pedestrians and cars. An alternative test

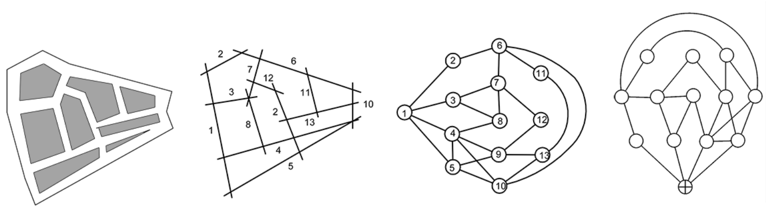

Fig. 3. Diagram taken from (Jiang and Claramunt, 2002). It presents: (a) fictive urban system; (b) axial map; (c) connectivity graph; (d) justified graph.

method to study users' movement in space is to analyze the axial map.

3. Analyses of axial maps

Analyses always consider a 2D layout model. All of them start from the subjective process of separating elements of spatial configuration and what is between these elements. The first subjective step involves considering all the visibility obstacles (also the third dimension, the height). Spaces are understood as voids (squares, fields, streets, rooms, etc.) between walls, fences and other impediments or obstructions that restrain (pedestrian) traffic and/or the visual field (Klarqvist and Jiang, 1993). The result is an estimated model where open public space is bordered and painted in contrasting colors (like black and white). A simplified contractual model is suitable for the start of the analysis (Fig. 3a).

The next step is to draw the possible smallest number of the longest lines of movement (lines of sight) in space. The whole space should be covered with them to show all the possibilities for movement. In this way an axial map is constructed (Fig. 3b). The resulting map is subjected to calculations, in which the main data become all axial lines and nodes of intersecting axial lines.

This way a graph of availability (*connectivity graphs*) is obtained from an axial map (Fig. 3c). It is a two-dimensional graph which can be constructed in several ways. It represents the relationships of accessibility between all axial spaces of a layout model. Axial lines which represent spaces are presented as circles (nodes) which are linked by lines showing intersections with subsequent axes. Nodes are numbered according to the numbers on the axes (Fig. 3c).

The number of immediate neighbors that are directly connected to a node is a local measure of *connectivity.* A graph should be reconstructed afterwards so that the considered space is placed at its bottom (*a justified graph*) (Fig. 3d). Such a space is called *the root space.* At the first level above the root space all spaces one syntactic step away from it are placed, on the second level, all spaces two spaces away, etc. Justified graphs offer a visual picture of the overall depth of a layout model seen from one of its points (Klarqvist and Jiang, 1993).

The algorithm described below serves to examine axial maps and count all four syntactic measures. The result of axial map calculations, a *spatial accessibility map*, or *spatial integration map,* is obtained, where lines representing the most accessible spaces are marked red, and the least available, blue (the same colors as in the case of observing people in real space). The algorithm can be used to calculate the shortest paths from one topologically specified point to any other point on the map. Such an operation is performed for each segment of the map. It turns out that the obtained results are almost always the same as the ones from studies where users are counted empirically. This data suggests that the SSA method is effective and expected changes in real are very likely.

4. Basic syntactic measures

The basic formulas and definitions listed below are fundamental for understanding the method which, based on them, was further developed and extended. There are four syntactic measures that can be calculated:

- Connectivity,
- Depth,
- Control value,
- Local and global integration.

4.1. Connectivity

Measures the number of neighbor axes directly connected to a space. It specifies the number of immediate neighbors of an axis. It is a local measure (parameter $k = 0$). *Connectivity* for axis 1 in Fig. 3 = 4.

4.2. Depth / degree of depth

It is defined as the smallest number of syntactic steps (in topological meaning) that are needed to reach one space from another. Depth is counted in a graph and is determined by parameter *k*. Parameter *connectivity* considers immediate neighbors and depth considers the neighbors of the *k-th* degree.

Connectivity and *depth* measures can be written as a sum:

$$\sum_{\mathrm{s}=1}^{\mathrm{m}} \mathrm{s \ x \ Ns} = \begin{cases} \text{conncectivity iff m = 1} \\ \text{local depth iff m = k} \\ \text{global depth iff m = l} \end{cases} \quad 1 < k < l/local\ depth(until\ k = 3) \quad (1)$$

where:

k	–	parameter,
s	–	operator (s is an integer),
l	–	the shortest distance,
Ns	–	the number of nodes with the shortest distance s.

Where 1 < k < l, usually three steps are adopted for the calculation of *local depth*, i.e. k is equal to 3 (this means that we consider lines within three steps from an axial line). We can also note that connectivity is equivalent to *local depth* if $k = 1$ (Jiang and Claramunt, 2002). *Local depth* in Fig. 3 for the root node (for $m = 2$) = $4*1+5*2 = 14$, *Global depth* in Fig. 3 for the root node = $4*1+5*2+3*3 = 23$, and in this case m = 3. To further explain the depth a simplified diagram of two rooms has been chosen.

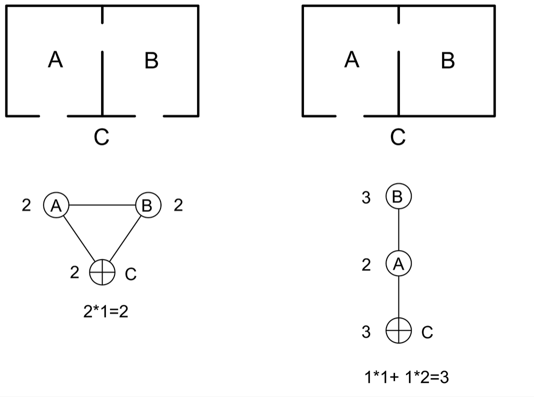

Fig. 4. Diagram taken from a Tim Stonor's lecture (*Spatial Layout Efficiency, National Capital Planning Commission on spatial layout efficiency*, 2013). The numbers are depth values of the nodes. It shows how depth depends on the connection of spaces.

4.3. Control value

It is the sum of the inverse values of the parameter *connectivity* of all neighbors from the selected axial line. It measures the degree to which a given space controls access to all immediate neighbors of the axis line. It takes into account all alternative connections which these neighbors have (Klarqvist and Jiang, 1993). This is a dynamic local measure. *Control value* for axis 1 in Fig. $3 = 1/2 + 1/3 + 1/5 + 1/4$.

4.4. Integration

Integration, also called availability, is a variable that refers to how a space is connected with other spaces in its surroundings. This is the key parameter leading to the understanding of the relationships that exist between users and the urban space and it is a global measure. It can be used to predict the potential of meetings in the space, because it is directly linked to the presence of people in a given location. The greater integration of the space, the more people will appear in it. For this reason, integration is sometimes called *accessibility* by SSA researchers !!!!(Szczepańska, 2011). In all studies conducted in different seasons and at different times of the day results confirm that there is a relationship between integration of the space and the presence of people in it. The most important observation is the fact that the axis system will lead users into the best integrated spaces in that system. Similarly, if less integration means less human presence, and uncontrolled space, it increases the chances of criminal and antisocial behavior in such structures.

Local integration

It is a measure of local integration, which shows the scale of the pedestrian movement. Its calculation takes into account the elements of the degree of distant depth equal to 3. Distance can also be taken as a ray anchored at the starting point of about 1250 m. For local integration measurements shall be taken at a distance of up to 5 syntactic steps.

Global integration

It is a measure of integration, measured throughout the system. It takes into account the distance from the starting point to all points in the system (Hillier and Hanson, 1984). A correlation was found between integration values and human appearance in the space. The more integrated the space is, the more people will appear in that space.

The relationship between the global availability of space (*global integration*), and the local availability of space (*local integration*) is the clarity and readability of the space (*intelligibility*). The better the correlation between these measures, the better user moving along a given axis is oriented in space and knows where they are in the context of the entire city (Szczepańska, 2011).

Spatial representation is constructed in a way that allows it to be used and processed in different computer programs such as: Axman, depthmapX, and many others. Syntactic measures and numerical results give a chance to draw conclusions about how the space functions. For example, a very isolated space characterized by a measure of *integration* is susceptible to increased risk of crime. Through such observation, it is possible to diagnose how to improve the quality of such space. Remodeling of the system, such as a change of connections in the space, generates opportunity to tackle the problem and predict how the newly designed space will function. Results of analyzes are presented in an understandable way. The way in which a problem is illustrated, shows the cause and solution, and is suitable for presentations during public consultation.

5. Main application and objectives of space syntax analysis

Because the method has fractal properties, it is possible to use it to study micro and macro levels. The availability inside buildings and inside neighborhoods or cities can be explored in the same way (Hillier and Vaughan, 2007). Although it can be concluded that space affects the sense of community, it can be also predicted how the form of space will affect the frequency of interaction (level of neighboring inhabitants). This can be achieved by creating a common infrastructure in public spaces, friendly, accessible streets, and taking an informed choice in positioning doors and windows (Talen, 1999).

The methodology derives from Kevin Lynch's way of thinking about the city (Lynch, 2011) and refers to his *mental maps*. SSA methodology continues his way of thinking about space, examines and explores urban planning from the human perspective, not from the bird's perspective. Charles Landry, in his publication describing the creative city, claims that SSA can be regarded as a relevant technique in contemporary way of thinking about cities, since „The main resource of the towns is their residents, human intelligence, their desires, motivations, imagination and creativity" (Landry, 2013).

In this holistic approach, users and their actions are a major determinant of how a space should look and function. An analogy to the space as a functioning whole can also be found in the well-known theorem of Le Corbusier: a modern house is considered as a *machine for living* (Corbusier, 2012); in SSA the city is a machinery of relationships between people and space.

Although primarily SSA was used only for urban spaces, now it is possible to use it also at a micro level (for rooms or buildings). It is used in most cases to study pedestrian movement. Other goals which could be achieved with SSA are assessing cyclists' movement or evaluating the use of public transport. Initial observation was that space is created by its users, and is connected with them. Users are creators and adaptors of the space at the same time. They can adapt it to their own way of life, while at the same time their behavior is shaped through this space (Pindor et al., 2013). The method of space syntax analysis stands on the boundary between different scientific disciplines. A number of studies have appeared which tackle the issue of space measurement.

In its initial form, SSA focused mainly on patterns of pedestrian movement in cities. The basic aim has subsequently been extended to a number of other aspects, such as modeling urban traffic, predicting air pollution levels, assessing the occurrence of burglaries in different neighborhoods and estimating the potential for retail development in the streets (Ratti, 2004).

Space syntax method is like grammar used to arrange spatial elements and analyze them. The first objective of the analysis is understanding the users. Through observation of where and how people move in the existing spaces, it can be predicted where to locate its specific functions. The value of understanding the relationship between the users and the space lies in predict how spatial configuration will shape user experience. The city is regarded as the penetration of the physical layer into the social layer (Hillier and Vaughan, 2007). Analysis of space syntax as a tool for sustainable development can be used to search for balance between environmental, social and economic aspects of the considered space. Analysis can be divided into stages consisting of a diagnosis and a prognosis. A pre-defined spatial problem is subjected to spatial analysis, which visualizes its causes and provides opportunities to alleviate it.

6. Criticism

One of the best-known critics of the method is Carlo Ratti from Massachusetts Institute of Technology. In his publications, he questions the validity of SSA method. He points out that the SSA method is not precise, that it is based on a subjective feeling, and that it distorts the true picture of the space. He also said that the form of the analysis is too simplified, because retreating only to the second dimension does not show the reality (2004). Ratti also criticizes the fact that the syntactic analysis of space syntax can give quite different results for a similar space. He received an immediate rejoinder by Hillier in his article from 2004. Both scientists argue whether the method is sufficiently objective. While the dispute is still not resolved, both are able to find arguments to support their point of view.

7. Conclusion

Syntactic analysis is a relatively young method, nevertheless in some countries it is seen as an essential planning tool. It brings concrete results, translatable into real space. It may be evidenced and easily shows why a problem arose in a specific space, and shows in a legible manner what the planned changes will bring. It helps to answer the question of how to get the space where people will be happy to come through action planning. It lets us get to know the relationship between the various structures making up the urban fabric. In combination with traditional methods of analysis of urban, sociological and empirical observation of users it provides a comprehensive tool to balance development, necessary for planning spatial structures.

References

Benedikt, M. (1979), 'To take hold of space: isovists and isovist fields', *Environment and Planning B: Planning and Design 6 (1)* pp. 47 – 65.

Corbusier, L. (2012), *W stronę architektury*, Centrum Architektury, Warszawa.

Emo, B., C. Hölscher, J. Wiener and R. Dalton (2012), 'Wayfinding and spatial configuration: evidence From street corners'.

Hillier, B. (1996), *Space is the machine. Machine A Configurational Theory of Architecture*, Space Syntax, London.

Hillier, B., A. Leaman, P. Stansall and M Bedford (1976), 'Space syntax', *Environment and Planning B 3(2)* pp. 147 – 285.

Hillier, B. and A. Penn (2004), 'Rejoinder to Carlo Ratti', *Environment and Planning B: Planning and Design 31(4)* pp. 501–11.

Hillier, B. and J. Hanson (1984), *The social logic of space*, Cambridge University Press, Cambridge.

Hillier, B. and L. Vaughan (2007), 'The City as One Thing', *Progress in Planning* **67 (3)**, 205–230.

Jiang, B. and C. Claramunt (2002), 'Integration of Space Syntax into GIS: New Perspectives for Urban Morphology. Transactions in GIS', pp. 295–309.

Klarqvist, B. and J. Jiang (1993), 'A Space Syntax Glossary', *Nordiskarkitekturforskning 1993:2* pp. 11–12.

Landry, C. (2013), *Kreatywne Miasto*, Narodowe Centrum Kultury, Warszawa, p. 25.

Lynch, K. (2011), *Obraz miasta*, Archivolta, Węgrzce.

Pindor, P., A. Skorupka and J. Szczepańska (2013), 'Psychologia i składnia przestrzeni'.
URL: *http://www.sztuka-architektury.pl/index.php?ID_PAGE=32875*

Ratti, C. (2004), 'Space syntax: some inconsistencies', *Environment and Planning B: Planning and Design* **31**, 487–499.

spacesyntax.com (2014).
URL: *http://www.spacesyntax.com/*

Spatial Accessibility & Human Behaviour - Designing places for People, Space Syntax - Christchurch (2013).
URL: *https://www.slideboom.com/presentations/799272/Tim-Stonor_Spatial-Accessibility-%26-Human-Behaviour_Align*

Spatial Layout Efficiency, National Capital Planning Commission on spatial layout efficiency (2013).
URL: *http://www.youtube.com/watch?v=_MBZhNAaZL4*

Szczepańska, J. (2011), 'Demokracja Przez Projekt? – Wykorzystanie Teorii Space Syntax Do Zrozumienia Współobecności różnych użytkowników w przestrzeni publicznej'.

Talen, E. (1999), 'Sense of Community and Neighbourhood Form: An Assessment of the Social Doctrine of New Urbanism.', *Urban Studies. 36 / 8* pp. 1361–1379.