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Cross Inspection: Art Space vs. Spatial Syntax.

From description method to design method

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ABSTRACT

The paper tests the hypothesis of mutual complementarity of two methods of spatial analysis - spatial syntax and art space. The difference between the methods is that the first, mathematically, according to certain rules, reveals the structure of the movement, and the second, according to certain rules, designs the navigation structure. For the first structure, the position of the path segments is sufficient to assess their accessibility within the street network; for the second, a mental presentation of this position is needed due to the semantics of the paths of movement in order to participate as a landmark in navigation. However, for both approaches, pragmatic accessibility and a certain orientation of the elements of the spatial structure - the paths of movement and perception - are important. This becomes, on the one hand, the basis for inspecting the theoretical navigation structures of the art-space for the degree of their "accessibility" using the method of spatial syntax, and on the other hand, for inspecting the "syntactic" structures for their suitability for navigation. As a result, we confirm that the segmental analysis of spatial syntax by the factor "integration" has a cognitive basis and is close to the mental presentation of space when constructing a navigation scheme for art-space.

KEYWORDS

Urban design, mental navigation, spatial syntax, structure, diversity

1 INTRODUCTION

Good intelligibility and easy orientation cannot be achieved in a monotonous urban environment. On the other hand, unstructured diversity creates chaos, loss of recognition of such space and disorientation. The orientation in the space of a driver differs from the orientation of a pedestrian or a cyclist both in the scale of the perceived space and in its semantics. The content of the environment and its compositional diversity is important when perceived precisely from the position of pedestrian movement, when the object of design is a new or reconstructed residential area, which, under certain conditions, can become a work of urban planning art, diverse in content. If we admit that any work of art must have an author and a certain depicted reality or imaginary space as in painting, literature, theatre, architecture, then we must admit that in addition to a real physical space with buildings, an imaginary artistic space can be conceived in a city project. The theory of spatial syntax asserts that the real space of a city, represented by a network of streets, successfully “controls” the movement of a person, since certain cognitive abilities of a person are embedded in this space. This means that by understanding these cognitive features of urban space, it is possible to create not only a functionally useful urban environment, but also a separate artistic space that will serve as navigation in real physical space and at the same time create an imaginary reality with an imaginary dimension of space. Thus, the theory of linear perspective made it possible to increase the imaginary dimension of the space of a painting (Rauschenbach, 1986). The composition of the idea running through the entire epic novel increases its imaginary meaningful “depth” (Kolontay, 2020). The perception of the city through the huge transparent wall of the Seagram Building or Glass House transforms the external environment into an artistic picture, changing the depth of the interior space. We called the methodology that provides navigation and forms an imaginary art space when designing a city Art-space (Kolontay, 1987, 2019). Since this technique is intended for the architect, it should be directly embedded in the design process language without the distraction of mathematical transformations. Therefore, in Art-space only two languages are used - natural and graphic, or rather their combination in the form of "verbal geometry".

2 ART-SPACE THEORY

2.1 Existing approaches to the mental representation of urban space in the process of orientation

The Cartesian coordinate system provided a high accuracy between the perception of architectural design drawings and the perception of a completed construction project. In urban planning, there is no such precision between project and implementation. If the architect visually perceives the project of the city as a whole, then the inhabitant of the city recreates its image mentally in parts in the process of spatial orientation. Since residents are rarely lost in their city, it can be assumed that they use some kind of flat "coordinate system" to read and understand the structure of urban space. Moreover, let us assume that the structure of such a flat navigation system will be the structure of the urban space, which on the mental level organizes the diversity of the urban environment.

Existing research on perception and orientation in urban space moves in four main directions: 1) within the framework of cognitive psychology and sociology through the construction of mental maps of the city with the help of residents (Lynch, 1960; Gottdiener and Lagopoulos, 1986;

Siegel & White, 1975; Tversky, 1998 and etc); 2) within the framework of cognitive linguistics through the analysis of spatial relationships in natural language (Talmy, 1983; Langacker. 1986; Herskovits, 1986; Fauconnier, 1985, etc.); 3) within the framework of cognitive neurobiology through the study of the brain hippocampus, which is responsible for spatial memory (Hartley T, et al. 2014; Bellmund J, et al., 2018); 4) within the framework of the methodology of spatial syntax through the mathematical analysis of the structure of the paths of movement in the city (Hillier & Hanson, 1984, etc.).

Spatial syntax for segment analysis of a city uses two cognitively important elements of a person's spatial movement: a path and an intersection or turn of a path, and as a goal - the degree of integration of paths into the structure (Al_Sayed, et al., 2014). However, since he leaves out the semantics of paths, the goals of movement, the orientation of a person and the social goals of the urban project as a whole disappear, which cannot be reduced only to the integration and structure of the network. The conclusions of cognitive neuroscience that spatial orientation involves landmarks-places preserved in the cells of the human brain and a regular spatial grid (Hartley T, et al., 2014) are important, but insufficient for modeling spatial navigation. Think aloud mind mapping has the greatest history of urban space structuring. For more than 60 years, various researchers have been improving the five categories of the spatial image of the city, declared by Kevin Lynch - paths, districts, landmarks, edges, nodes (Lynch, 1960). Siegel & White (1975) attempted to explain the mental spatial geometry of a city as a system of three elements - landmarks, routes and survey knowledge, connecting point and line elements. Beattie proposed keeping the five categories of Lynch, but systematizing them: "network of paths punctuated with orientating devices in the form of nodes and landmarks and discriminated into districts which are clearly defined by boundaries and edges" (Beattie 1990, p. 113). Tversky (1998) first proposed four elements important for orientation - startpoint, reorientation (direction), path / progression, end point. But, then, in his latest publication, he connects the conventionally abstract categories of the geometry of urban space with their objective counterparts described by Lynch: "Points are otherwise known as dots or nodes or places or ideas; lines can be called links or paths or connections or relationships; boxes can be termed regions or areas or containers. Center is also known as middle, focus, core, crux, hub, foreground."; "Some lines are edges: they can be boundaries, barriers, separating one set of things from another..." (Tversky, 2019, p.153). The methodological problem of mental maps is that, on the one hand, they objectively describe the phenomenology of specific places. On the other hand, scientists subjectively interpret research results taking into account ideas about the "correct" structure of urban space and the orientation system. It is the scientist's serious interference in the research results, which does not allow us to speak about the objectivity of the methodology of mental maps and the justification of the categories of spatial orientation.

2.2 Existing Linguistic feature of the elements of the mental space of the city

Analyzing the spatial relationships in natural language, linguists concluded, that a place in space begins to exist in consciousness only when it is correlated with another place. "Since the only way to describe the place of an object is by using other objects as reference ..." (Herskovits 1986, p. 33) Thus, the description of space looks like a system of paired relations encrypted in the meanings of the prepositions and adverbs of place and movement. Leonard Talmy largely opened the debate in cognitive linguistics about the specifics of spatial prepositions by reporting, "The actual "literal" referent of any spatial expression, such as an English preposition, is a particular assemblage of primitive geometric components in the form of an abstract schema "(Talmy 1983, p. 258). Linguists point out the importance of paired spatial relationships such as "primary object - secondary object", "object-reference object", "figure - ground" (Talmy 1983), "trajector" - "landmark" (Langacker 1986), "subject of the preposition - object of the preposition "," located entity-reference entity "(Herskovits 1986), etc. However, we are convinced that in order to reveal the meaning of any preposition of place, it is necessary to establish a relationship of place not with one, but with a large number of referents. For clarity, linguists often use the concept of "scene", which is perceived as a static projection onto the picture plane with an unambiguous position of the observer-researcher. For a correct understanding of the statement about the location of a place in a city, it is important to orient the "urban scene" itself. It is important to understand from which direction the subject can arrive to the place in order to start orientation further, guided, for example, by the advice "the clinic is located not far from the park". An accurate verbal description of the position in the urban space by one of the eight horizontally prepositions requires the establishment of a mental connection with other prepositions (Table 1). So the preposition "in front of" is applicable for navigation, if the place "behind" is known, the central reference point A is known, which is "between" the previous places; another central reference point B is known, located in a common connection with A. Moreover, it is essential to understand in which place the position "close" goes to the position "far" from the reference centres. Establishment of the reference-border C with the preposition "between" ensures the delimitation of the zones of influence of the two centres. In conclusion, the establishment of the rear boundary of the zone of influence of the centre with its reference point D ensures the recognition of the centre A from all directions of movement.

All prepositions are interconnected and it is impossible to understand the meaning of one without the use of all others in conditions of mental navigation in the urban space. If all relations are established between the two centers A-B, with the boundaries of the C-D, then each preposition should indicate the position of the conditional main center of space A, the position of the boundaries of the zone of influence of the center, the direction of the main movement from the border C to the center A.

Table 1: The position of prepositions in relation to the centers and boundaries of the mental space determines their own meaning

	REFERENCE CENTER «B»		REFERENCE BORDER «C»		REFERENCE CENTER «A»		REFERENCE BORDER «D»
1	2	3	4	5	6	7	8
Behind B Beyond B On the left B On the right B	**In B** Within B In the center B … Between the boundaries of influence B	**Far from A** Far away A Away from A Near B Next to B …	**Between A and B**	**In front of A** Against A Beside A Next to A At A By A Opposite A Near A Outside A Around A Far from B Far away B	**At A** Inside A In A Within A In the center A In the middle between opposite borders C,D	**Behind A** Beyond A On the left A On the right A	**Opposite border C**

It is surprising that among the variety of prepositions and adverbs of place, only one preposition "in front of" accurately indicates the place and the main axis of orientation. The prevalence of "imprecise" prepositions of place in the language suggests that we use them for small or visible spaces, as well as the importance of combining and complementing visual and mental spatial experience.

To demonstrate the elements of the structure of the mental space - center, border, axis-path, we will use an imaginary orientation in convex spaces of a rectangular conditional room, similar to the one used by Bill Hillier (2003, p 06.6-06.7). When verbally describing three situations (Figure 1, a, b, c), we always use three categories. The center is determined equidistant from the boundaries of the room. The axis is like a path through the center between opposite boundaries. Borders are like a long path around the center. Each of these categories gives a different imaginary dimension of the same physical space, measured by the remoteness of the location from the outer border along the path of movement. With the visual unambiguity of the location of the agent in Figure 1 (a, b, c), the verbal description requires clarification, since the room itself is not oriented. It is necessary to provide connection A1-A2 with the external space R2 (Figure 1d). In addition, in order to get rid of the references of the human body (right-left), it is necessary in our room to make an additional connection A1-A3 across the border "B3" to the second room of this apartment R3. Moreover, now the most important in the spatial image are the places of intersection of the boundaries of the apartment, now they are the centers of reference. Paradoxically, the oriented center is topologically always at the same time the border of its opposite borders and vice versa. We see here an important in Gestalt psychology and linguistics mutually generating pair of figure and background, “mental spaces”, when one meaning generates another (Talmy, 1983; Herskovits, 1986; Fauconnier, 1985, etc.). In the experiment with the room, we used a conditional person as an observer subject with low vision, but with ordinary spatial imagination. Mental navigation presupposes the use of the considered complex algorithm for structuring space. Modeling the structure of the mental space using natural language allows us to draw an important conclusion. *If a place is simultaneously in three topological dimensions: it is a border, a center and an axis, then it exists as landmark.*

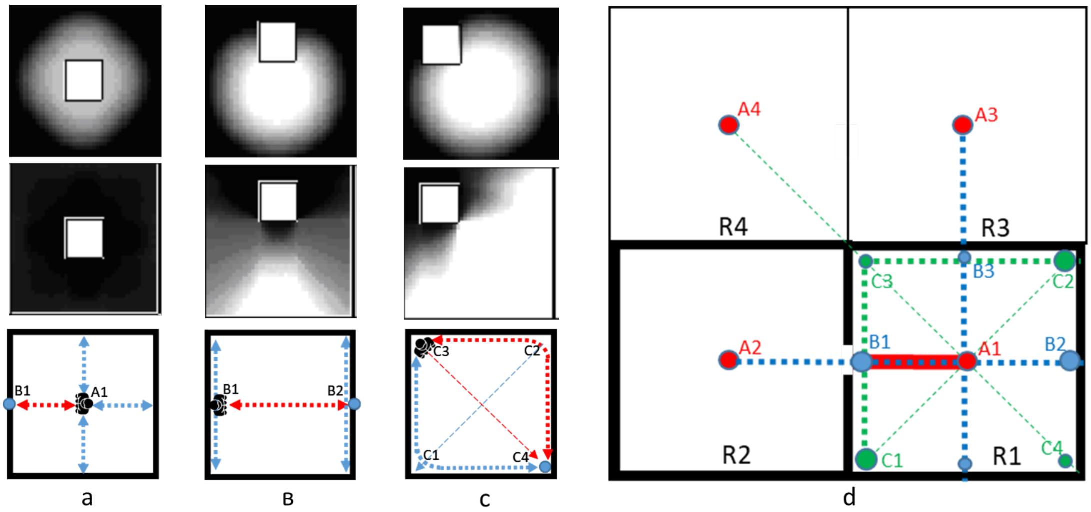

Figure 1: Modeling the structural elements of the mental space

2.3 Center, border, axis-path in art-space theory and spatial syntax

Center. Spatial syntax focuses on the topological properties of the center, on its ability to perform the “centrality” function using the highest values of “integration”, the lowest values of “depth” and the highest values of “choice” of street network segments (Al_Sayed, et al. 2014). In each of the three indicators of “syntax”, there is a center, a border, and a path-axis. However, the "depth" reveals the boundaries, and the evaluation of the "choice" gives the most active axes-paths. In the Art-space methodology, we define the ideal center as follows:

1) Equidistant location of the center in relation to the inner and outer boundaries of the zone of influence of the center, or located between borders with similar semantic properties (set by boundaries).
2) The place of intersection of the paths and the change in the semantic properties of the paths before and after the center in each direction (description through the paths of movement).
3) Gradual reduction to zero value of the intervals of movement from the outer boundaries to the center (description through changing the interval and semantic properties of the path segments).
4) The aim of the movement (description through social and semantic significance of place).

The border. Spatial syntax uses the boundary category in its analysis to denote the outer boundary of a city, or the radius of influence of each segment of the street network. In the first case, because of the analysis, "syntax" forms the global central structure, in the second - the boundaries and centers of local parts of the city (Hillier et al., 2012). When analyzing the links within the system, the authors of the "syntax" do not use the concept of "border". However, in the intervals of street segment weights by the centrality factor, a spatial boundary is expressed, indicated by one segment or a whole set of segments with a similar centrality value. In the Art-space methodology, we establish the external and internal boundaries of the zone of influence of each centre. We mark all borders with paths of movement or intersection of paths of movement. The external border is established conventionally along the border of the built-up area or by dividing the zones of influence of similarly important landmark centres or development areas. We form the inner border in the longitudinal and transverse directions of the paths of movement. We set the transverse path boundaries with a variable interval between the reference points towards the centre, forming excellent ring-shaped belts around the centre, similar to Thünen's rings. We form longitudinal boundaries with different building properties from opposite sides along the traffic path.

Axis-path. The theory of spatial syntax considers segments of city paths as the main means of identifying the priority structure of movement (Hillier & Hanson, 1984). Each individual segment of the street network on the axial map does not have an orientation towards the center or centers, but after the angular topological analysis, differences appear in the indicators of the accessibility of network elements and an orientation between the center and the periphery is formed at the global and local levels. "Syntax" transforms some segments into distant boundaries, and others into centers - "root" spaces, which is clearly seen when transformations in the form of "integrated j-graph" (Hillier, 1984, 2009). According to the Art-space methodology, each end of a path segment, on the one hand, functions as a border, and on the other side, functions as a center. Each segment has a unique metric dimension and a unique distance in relation to the center of orientation. Each segment of the path is marked with a unique architectural and semantic property. We call the system of the main maximally rectilinear axes-paths the main navigation system, and their intersection by the main center of navigation or the coordinate center. Deviation from the rules Art-space becomes an artistic technique if the rules of the elements of the mental space we have considered are valid in the project.

Spatial syntax tries to describe, as objectively as possible, the relationship between space and social behavior in terms of integration and normalized street network accessibility. The problem arises when interpreting "syntactic" structures from the point of view of their "objective" development, which is problematic due to the non-obviousness of the goals of social development and the irreducibility of the form of space to functional content. Even the concept of "movement economies" as a manifestation of the concept of "centrality", for all its importance (Hillier, 1996), does not cover the entire "social logic of space."

Art-space chose the *"centrality of diversity"* as the goal of shaping the space as a reflection of social life in the artistic space of the city, which we create by the navigation system and capitalize as a cultural value, and at the pragmatic level, we provide a person's free orientation within the boundaries of the project.

2.4 Art-space theoretical navigation structures

Navigation structure of the path segment. The straight-line segment of the path is the simplest basic element from which the street network of any city is built. Our task is to consider how the formation of varieties by dividing the path into segments affects the orientation and can even form a certain artistic image of space in the process of movement from the beginning to the end of the path. Segment analysis of a given experimental path would show that topologically the most significant in terms of "integration", "depth" or "choice" in a linear structure is the centrally located segment (Hillier, 1996, p 80). The navigation agent would call this place "midway." *Midway modelling is the main art-space technique* (Fig. 2).

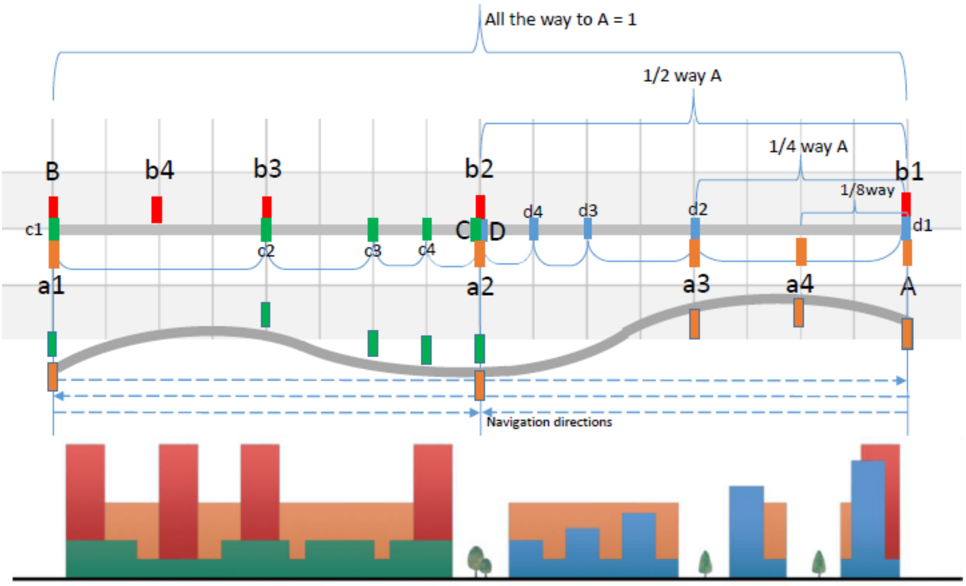

Figure 2: Modeling navigation and diversity on a path segment

The key landmarks in art-space: the beginning of the path, halfway to the goal, quarter of the way, half of the quarter of the way and the place at the goal. All these places indicate the distance from the outer boundaries (the place where the movement starts) to the centre (the purpose of the movement). At the same time, we see a coherent set of unique places, each of which is simultaneously the centre of one space, the border of another and indicates the direction to the main centre. Art-space provides for the maximum division of any segment of the path in four sets of landmarks simultaneously (set A, B, C, D). This capability is based on the multidirectionality of segments towards three border centers and a limited set of four easily cognitively distinguishable architectural properties that have a common semantic basis. They form pairs of similarity, opposition and complementarity according to the principle of the semiotic square A, B, -A, -B. The composition of the four types of street building with differentiation of landmarks by their dimension can look like shown in Figure 2. «A» set of objects form building blocks of different lengths. Set B - consists of multi-story infill buildings of similar height. Set D-buildings with variable descending number of stores. Set C - horizontal row of service objects. Regardless of the total length of the path AB and the degree of straightness or deformation, due to the topological principles of division, the continuity and accuracy of positioning during navigation does not change. The metric distance when designing any segment of the path is calculated using the geometric progression formula:

$$a_n = a_1 \times 2^{n-1} \quad (1)$$

Where a_n is the planned metric distance of the path in accordance with the ordinal number of the segment, path interval or landmark, a_1 - is the metric size of the first segment of the path closest to the navigation center. The considered semantic and topological modeling of the path of movement constantly changes the mental imaginary scale of real space, then compressing, then expanding it, then approaching, then moving away the goal of movement, then doing it simultaneously. In this case, it is the emotionality of the path due to the pulsating space that speaks of the accuracy of the perception and recognition of the embedded navigation system.

Monocentric navigation structure. The transition from linear to spatial navigation implies a significant increase in the number of paths and potential landmarks in different directions. However, the possibility of an accurate verbal description of space limits the set of such directions as - "in front", "behind", "on the right", "on the left", connected directly with the bodily spatial experience of a human being (Herskovits, 1986, etc.). The human body connects on itself the main coordinate center of two axes of motion intersecting at right angles. Art-space uses a Cartesian coordinate system transformed into a topological monocentric navigation system for numerically indicate the distance of orienting places, considered by the example of movement along a linear segment of the path (Fig. 3a). The path along the + Y-axis is taken as the main one, as that which is "in front" of the coordinate center, the path along the -Y-axis is "behind" the center. We provide mental recognition of the center by changing the polarity on the X and Y-axes and changing the architectural properties of the building at the intersection of the axes, which we denote by a pair of similar and a pair of opposite colors that form semantic integrity. The four boundaries of the zones of influence of the navigation center are marked with numerical values 1 (all the way); 1/2 (half way); 1/4 (quarter of the way); 1/8 (half a quarter of the way) with differentiation of positive and negative values and colors along the coordinate axes. Navigation is impossible until the boundaries belonging to the center are set, and a closed contour of equidistant boundaries is formed (Fig. 3a). This means that the path "around the center", which began at the boundary with a value of ½, must cross all axes exactly at a distance from the center with a value of ½. If the above conditions are not met, in the inter-axis space during navigation, the connection with the coordinate center will be lost. In a real urban project, the paths marking the main coordinate axes can be of different lengths, the circular paths-boundaries can be strongly deformed, but the proportions of dividing the axes into segments should correspond to formula 1.

At the turning points when moving along the ring, an instant loss of orientation occurs, which is restored by the visual the diagonal towards the coordinate center. In a theoretical ideal navigation structure, all path segments should be straight with mutual intersection at right angles, their metric dimensions should be half the outer segment and twice the inner segment. In this case, any intersection in relation to the nearest neighboring intersections or segments will be shifted by a third of the way towards the main center, as if indicating the direction to it. To increase the variety and accuracy of positioning, it is necessary to transform the boundaries of the navigation structure in Fig. 3a to new local reference centers as shown in Fig. 3b. The detailing of the navigation system should simultaneously solve two issues - to ensure the continuity of movement due to the uniform of the path and to ensure the discreteness of the path in the places of centers and boundary intersections for their cognitive presentation. We reach a compromise with two-color marking of the axes-paths on the navigation model.

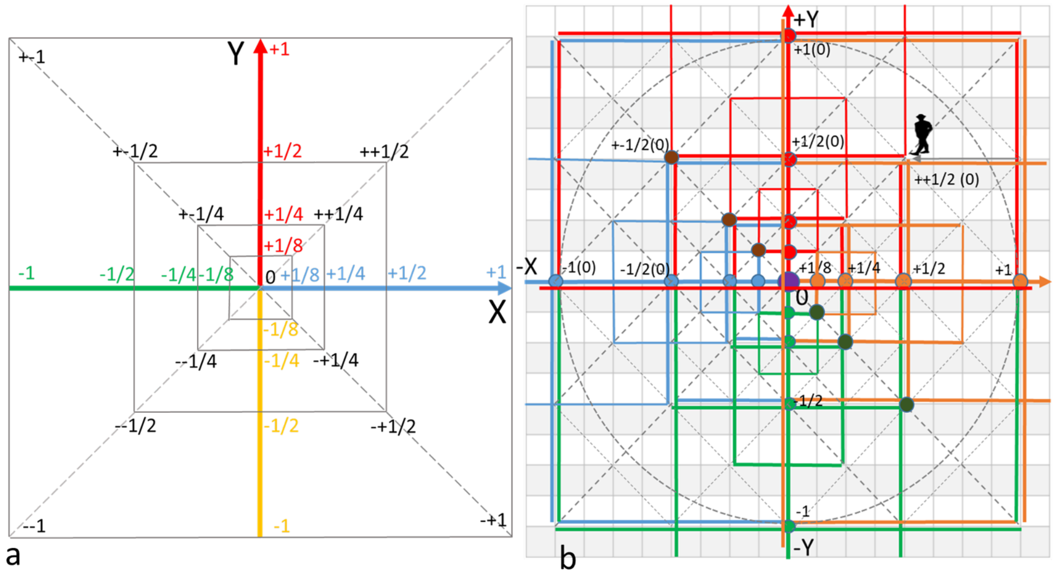

Figure 3: Construction of a monocentric navigation structure: a - basic variant with one center, b - detailed variant with local sub-centers.

We provide mental diversity by mixing four marking semantic sets, for example, urbanized, natural, urbanized-mixed, natural-mixed properties of the urban environment. The monocentric navigation structure has unique artistic properties: it forms an emotional image of a single shrinking space in the basic version and a continuous pulsating surface with “canyons” shrinking towards the center in a detailed version. Here, the emotionality of the image confirms the recognition of the structure as a whole work, in fact, a fractal topological space.

Most cities in the world, from the Roman military camp to the metropolis of London, Beijing or Moscow, are based on the prototype of a monocentric spatial navigation structure. From the point of view of art-space, the orthogonal grid of streets of American cities is not a navigation structure, but a metric engineering grid, on which any structure, including a monocentric one, can be superimposed. Perhaps for this reason, comparing the "normalized integration" of London and Manhattan is difficult (Ratti, 2004). The art-space methodology is important for the pedestrian perception of the city, where in a relatively small physical space it is necessary to create the feeling of a large, infinite, diverse space. When working with large spaces of cities, it is advisable to use art-space structures not for navigation and not for composition of artistic space, but for managing the development of territories, as is done in the Strategic Plan for London or Moscow, where a monocentric model is present in the system of territorial sectors.

Bicentric navigation structure. There are many cities with urban centers developing along the main avenue between the main squares or the main city parts, such as in the Australian capital Canberra. The art-space forms the navigation structure of this type by adding two monocentric structures, but with a change in the direction of the Y-axes, as if inverting the original structure along the X-axis, which now becomes the main one in each of the parts, as in Figure 4a. Only under these conditions will the architectural properties of the X-axis with equal polarities (++) form continuity, ensuring the integrity of the entire navigation structure and the recognition of each part. To detail the bicentric structure, like all others, the art-space uses *the general method of "projection" of properties.* We, as it were, project the properties of the opposite coordinate axes "Y" and opposite boundaries (-1X) onto the coordinate centers "0" and all internal boundaries -1/2, 1/4, 1/8 (Figure 4b). Diagonals are used as guides, which mentally connect certain turning points on the navigation paths. The most significant turning points for spatial positioning (+1; +1/2) are oriented by visual diagonals to two coordinate centers at once. Each coordinate center denotes with a numerical value “0;2” the outer boundary of the influence of the other center (Fig. 4b). Full detailing of the project is achieved when the properties of all boundaries that simultaneously belong to two navigation centers are set, and all the boundaries of the local parts are determined with the values of the centers - 1/2; 1/4; 1/8. A sign of a holistic reading of the bicentric structure is the artistic image of space simultaneously stretching and twisting along the X-axis.

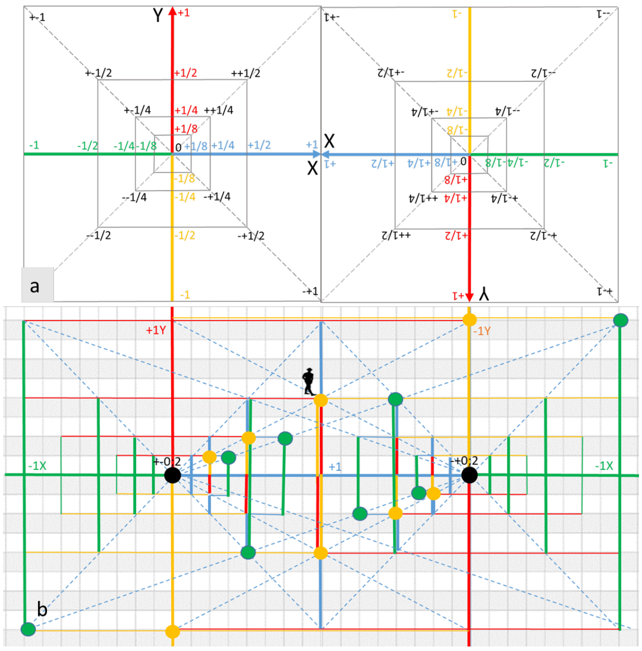

Figure 4: The structure of the bicentric navigation structure: a - formation by addition and "inversion" of two initial basic structures, b – detailing

Quadrocentric ring navigation structure. The use of this structure as the main one is a rare phenomenon in the history of cities. A city in the form of a topological flat ring or a closed spatial boundary arises if the central zone is an obstacle to urbanization in the form of a park, or a lake, as in the Vienna Aspern Seestadt, or a strictly protected historical zone, and the like. The broken ring is more common, for example, in the city plan of Karlsruhe. We ensure the orientation and uniqueness of the position of each element of this art-space structure by adding four monocentric structures according to the rules of the previous bicentric model (Fig. 5a). The result is an oriented diagonal stress. On the one hand, there is a kind of compression of space along the + X and + Y-axes, and on the other, stretching along the -X and -Y-axes. Detailing of the quadrocentric structure can proceed according to the scenario of monocentric, bicentric, and according to its own scenario (Fig. 5b). In order for the navigation to take place with an orientation to the boundaries of space, new virtual centers are created there, to which the maximum expansion and maximum compression of space occur simultaneously. When navigating inside a quadrocentric ring structure, the artistic effect of a curving space arises as a sign of an adequate perception of the entire inner diversity. The final methodological meaning of art space is the use of three theoretical navigation structures and various combinations of them to build spatial diversity of any complexity with a free orientation of a person and the creation of a certain artistic image of space (Fig. 8)

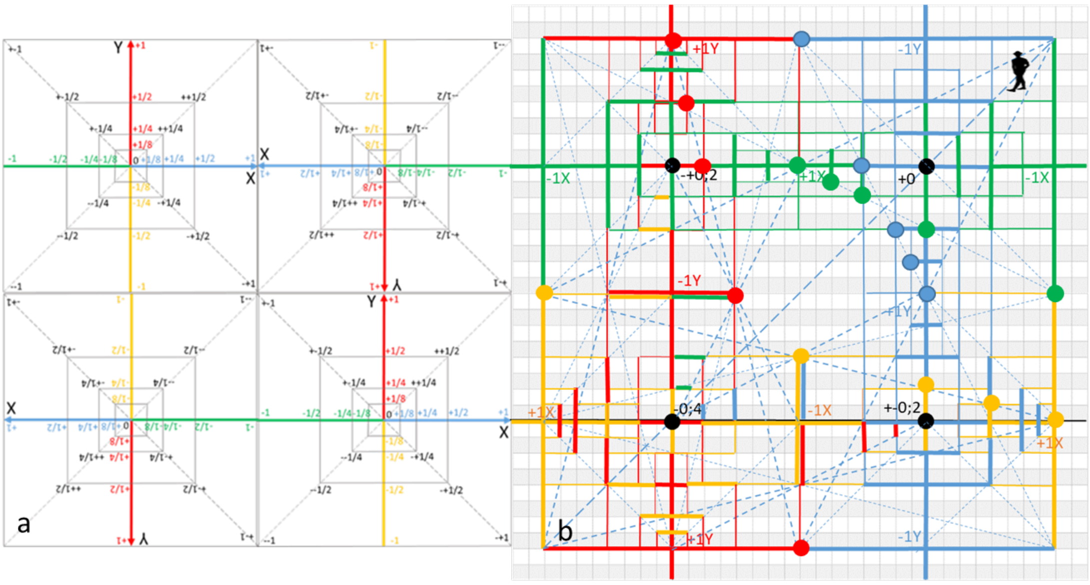

Figure 5: Construction of a quadrocentric circular navigation structure: a - formation by adding four initial base, b – detailing

3 METHODOLOGY OF ANALYSIS

Formulating an approach. The authors of the methodology of spatial syntax have always emphasized the cognitive and orienting effect of segment analysis, based solely on the priority of the configuration of urban street networks, without considering the functional and architectural semantics of the space. The spatial structure of the city is much more stable than its functional content, which motivates human mobility. This is what Bill Hillier had in mind, noting that "... more integrated local grid will have higher internal rates of movement due to the attractor effect of the local grid, before we even consider the load of attractors imposed on this by the movement economy process" (Hillier, 1999, p 06.19). Alan Penn said about the same: "... during design it is exactly the effects of the geometry of the layout that one needs to assess, and any assumptions about future trip motivations for individuals are more likely to be wrong than right" (Penn, 2001 , p 11.2). Despite the obvious reduction of the perception of space to bodily movement in segment analysis, for which "syntax" was criticized (Stahle et al., 2005; Pafka, 2017), the cognitive component of navigation on the street network in "Syntax" and Art-space is similar. It is in the turning points - the places where the decision on the route of movement is made, taking into account the degree of curvature of the path itself, in the convenience of straight-line continuous movement. The fundamental difference between the methodology of "syntax" (SS) and art-space (AS) is not even in relation to the semantics of space, but in the way of defining the central spatial structure. Therefore, the SS objectively calculates the central element by evaluating the degree of centrality of each segment within the given boundaries. In the AS methodology, the architect sets the central element and external boundaries as the main elements subjectively, taking into account their intended functional, social significance and the desired artistic effect during navigation. Further, the detailing of the typological structure and the establishment of belonging to the center (fixed interval) of each border dictate the position of each element in the AS. It is necessary to check the navigation capabilities of the SS through the degree of coincidence of the configuration of the central structure according to the AS and according to the SS method, taking into account the difference in methods. At the same time, it is possible to determine the degree of coincidence in terms of accessibility and navigation of the same internal elements of the AS and SS structures. We will carry out the stated analysis of both theoretical navigation structures and their implementation in the design structure of the city.

3.1 Assessment of the theoretical navigation structures of the AS according to the methodology of space syntax

Despite the fact that all SS algorithms "integration", "depth", "connectivity", "choice" have a certain specificity, they all calculate "centrality". Our first task is to determine one of the most efficient algorithms for analyzing AS. Given that the outer boundaries of theoretical structures coincide with the boundaries of analysis, it is to be expected that the definition of "integration" and "depth" should give the same results (Al_Sayed, et al. 2014). The structure of the center for "connectivity" and "choice" may differ. We will do the primary modeling on the simplest monocentric navigation structure in the basic and detailed version. For modeling, we used depthmapX programs (v 0.8.0) through the QGIS plugin (Space Syntax toolkit - v 0.3.9) and the standalone depthmapX net helper application (v 0.35). Both programs were downloaded from the official GitHub repository of the Space Group UCL team. To scale the monocentric model in the graph, the minimum segment size was taken as the average size of the city block in the axes of the streets of 125 m (1/8 of the distance from the outer borders to the center). Accordingly, the distance from the outer borders (1) to the navigation center (0) was 1 km or radius «n», the overall external dimensions of the model are 2x2 km. In a monocenric navigation structure, the number of segments between the center and the outer border in any direction from the center cannot be more than four. Therefore, we will use a scale of four plus one color. Four for the border segments, one for the center.

The best results in terms of the configuration of the central structure and hierarchy of boundaries were shown by the analysis of "normalized integration" and its analogue "total depth" (Fig. 6a, b). The analysis of "connectivity" does not allow differentiating the properties of each segment, forming conditional belt-borders with the same values around the center (6c). "Normalized angular choice" does not recognize coordinate axes in a monocentric structure as unambiguously central, assigning the same high potential to separate outer and inner boundaries (6d). It is also surprising that the color-coding of the “choice” model is not in symmetry, in contrast to the geometry of this AS structure. The preliminary conclusion on the syntactic analysis of the monocentric detailed structure of the AS indicates the greatest adequacy of the application of the "normalized integration" algorithm, which not only unambiguously reads the main coordinate axes, but also correctly marks the hierarchy of boundaries with color from the point of view of the navigation functions of the AS (Fig. 6a).

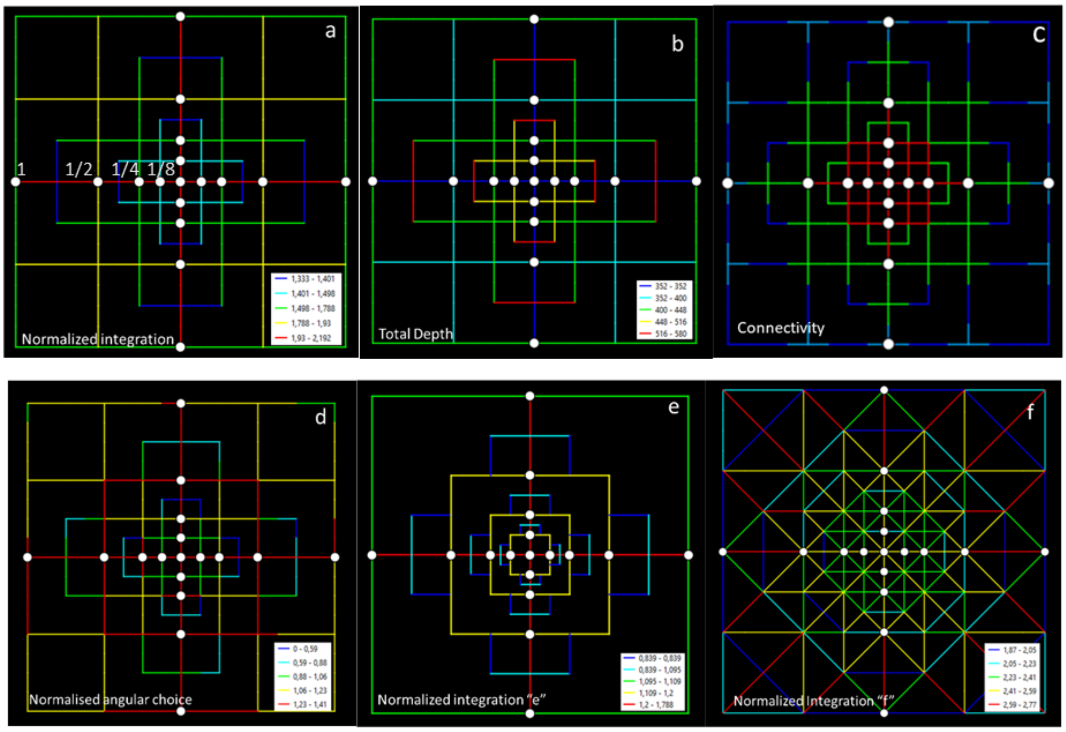

Figure 6: Analysis of the monocentric navigation structure Art-space using Spatial Syntax algorithms

The outer border segment with the index "1" is the most significant after the center "0" for navigation. Nevertheless, its accessibility weight is equal to the weight of the segment border with the distance value ¼ (green). The reason is obvious - the integrating force of the outer boundary will manifest itself only after establishing a connection with external centers and transforming the monostructure into a bistructure. Prior to that, the most spatially accessible after the center for the SS is the segment with the index ½ (yellow), which has a good coverage and connection area, since it is located in an advantageous middle place between the center and the outer border. The weight of segments-borders with an interval index of 1/4 and 1/8 decreases towards the center both in terms of the navigation significance of the AS and their integrating significance of the SS with a gradual decrease in the coverage area. From the considered regularity, a preliminary assumption can be made that its topological distance from the main navigation center for the AS and topological distance from all other elements of the spatial structure for the SS determine the significance of an element in the detailed structure of the AS in the function of a spatial reference point equally. At the same time, the design functional significance and architectural difference between the elements of the spatial structure can be established both on the AS and SS scales.

The structure in Figure 6e requires special comments. Here, all the inner boundaries of the zone of influence of the main center have the same normalized accessibility or integration (yellow), but different navigational significance (1/2; 1/4; 1/8) for a comprehensive understanding of the structure of space. We associate this with the absence of an alternative of motion or equal shortest connections with the entire space when moving along a circular closed path-boundary. Here, the only external communication is through the main coordinate paths-axes. Detailing a monostructure, as in Figure 6a, transforms linear boundaries into new local coordinate axes, and point boundaries into local centers with their own internal and external boundaries. At the same time, a structure of paths differentiated by accessibility and orientation is created. Diagonal connections, which are important for the construction of the navigation structure of the AS, are not logically integrated into the structure in the segment analysis using depthmapX, even with a multiple decrease in their weight (Fig. 6f).

Elements of bicentric and quadrocentric structures of the AS have similar patterns in "normalized integration" (Fig. 7), as well as monocentric. The only difference is in the used rating scale. Since in the bistructure the distance of the border (the opposite center with index (0; 2) increases by one interval, the SS scale has five plus one intervals, and the general conditional simulated parameters are 2x4 km. In the quadrostructure, two added intervals of the distance of opposite centers (0; 4) were reflected in seven intervals of integration, with conditional parameters of 4x4 km.

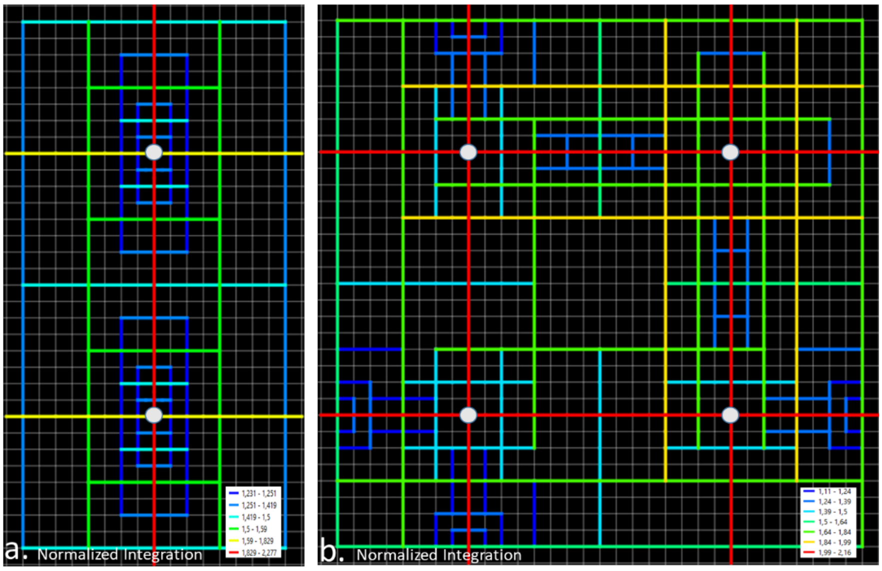

Figure 7: Analysis of the bicentric (a) and quadrocentric (b) navigation structures of Art-space by Spatial Syntax

3.2 Combining Art-Space and Spatial Syntax in a city project

An architect who starts designing or evaluating a developed project using the art-space methodology first makes a decision on the concept of an artistic image of a space that most closely matches the size of the projected territory, functional, transport organization, social and economic objectives. The artistic concept of space, its complexity and diversity is set by the considered three basic structures of the navigation system (Fig. 3-5) and four derived combinations from the basic ones (Fig. 8). The options for detailing and compositional deformation of structures during design are not limited.

The construction of the derivatives of the structure is based on the topological three-dimensionality of mental space, associated with three dimensions of place - as center, axis and boundaries. We combine these functions in three corresponding navigation systems - mono, bi and quadro. The structure "a" in Figure 8 provides the greatest ease of orientation with a high content diversity of space. Structures "b" and "c" reduce the diversity of elements, but create a compositional originality, making it difficult to navigate the circular path (b) or forming center nodes with diagonal intersections under 45 * paths. The “d” structure, unlike the other three, is open, incomplete, since some of the centers and coordinate axes of bi and quadro structures are located at the boundaries of the design space, and assume completion by including the surrounding external space. Due to this, in the same physical space, the derived structure "d" is able to create an image of the largest and most diverse space.

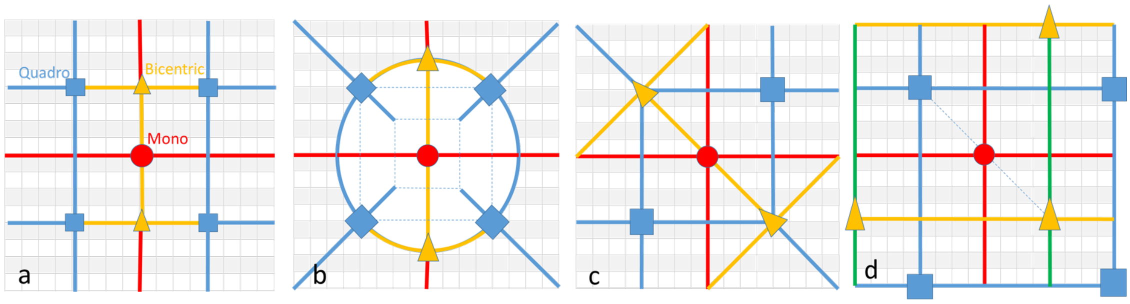

Figure 8: Four types of Art-space derived navigation structures obtained by adding three basic ones - mono (red), bi (yellow) and quadro (blue)

We demonstrated the use of Art-space in scenario design at REAL CORP 2019 (Kolontay, 2019). We presented the results of modeling an imaginary spatial navigation using the example of a master plan for the structurally complex Vienna district of Aspern Seestadt at REAL CORP 2021 (Kolontay, 2021). It is convenient to show the interaction of the derived structures of art-space and spatial syntax using the example of the same Aspern project, with an area of 240 hectares, developed by Tovatt Architects & Planners AB (Fig. 9).

The authors of the Aspern district project did not use the art-space methodology, therefore, in the ideal configuration, there are no considered basic navigation structures, but there are fragments of three derivatives shown in Fig. 8b, 8c, 8d. By changing the level of diversity of the design structure in comparison with the original (Fig. 9a) by embedding detailed monocentric (9b) and derivative (9c), we increase the proportion of street network segments with high rates of "normalized integration" and availability, marked in red on diagrams and histograms (9d, e, f). The simultaneous use of art-space technology and spatial syntax expands the field of understanding of the design solution. Thus, by increasing the orientation of the street network and the intelligibility of the design solution for the AS, we simultaneously increase the normalized accessibility for the SS. We see this in Figures 9e and 9f, where the number of red segments of the paths with the maximum accessibility or integration is even greater than the segments corresponding to the main coordinate axes. The use of compound three-part derivatives of navigation structures should certainly increase the diversity, meaningfulness of the spatial composition, but if we have the necessary variety of architectural means for each basic structure.

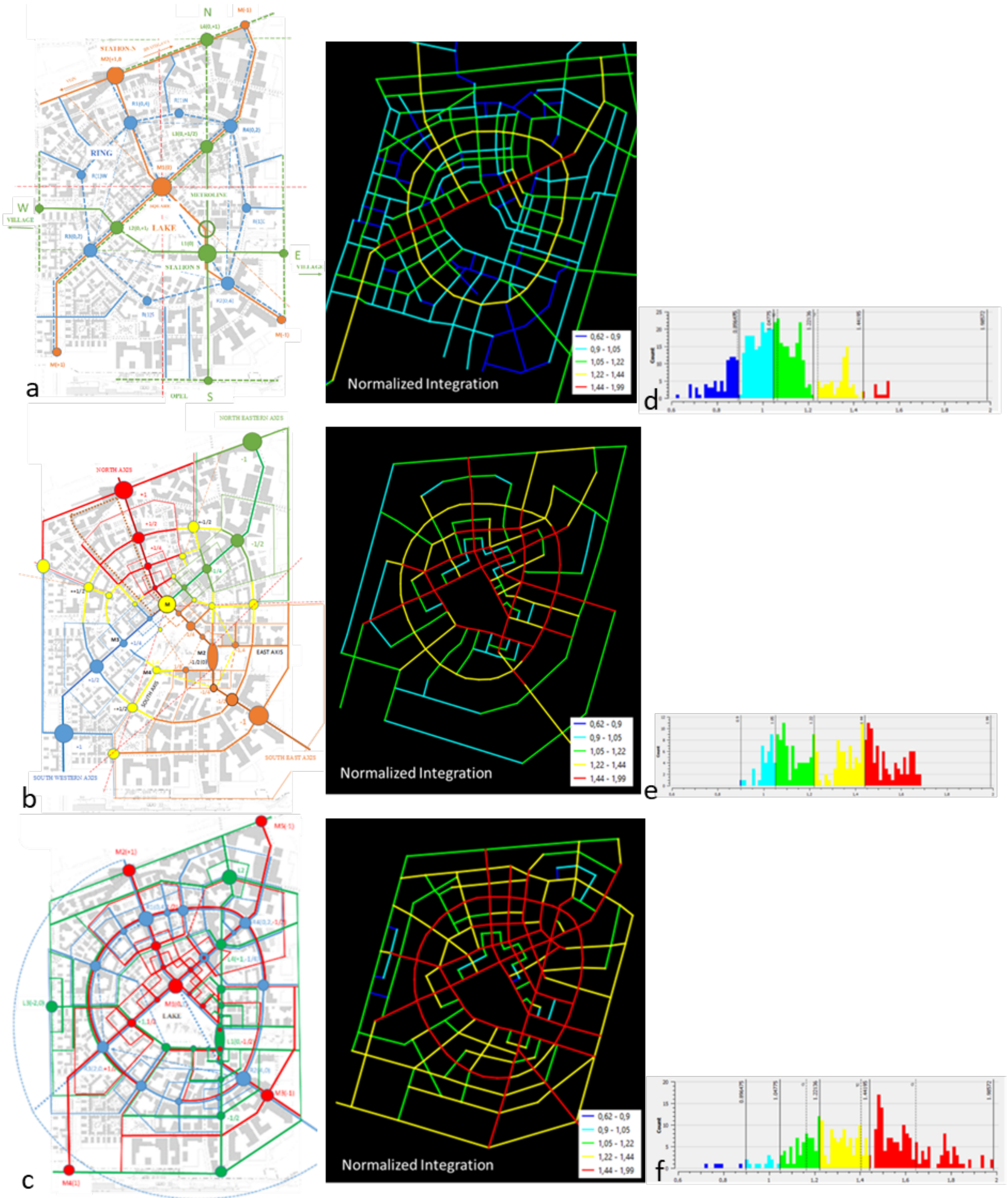

Figure 9: Comparison of the spatial structure of the Aspern area (project by Tovatt Architects & Planners AB) according to the Art-space methodology (left) and Spatial Syntax (right)

However, with large deformations of the paths of movement, their poor recognition arises and, accordingly, the artistic effect of space disappears. Therefore, the detailing of bi and quadro-structures (9c) is difficult to read in the Aspern project due to the deformations of the paths. This is also confirmed by the integration assessment scheme (9f), where a large number of unidirectional segments of the same color with the same accessibility appear. Outside the main coordinate axes, the structure of 9f began to resemble a "natural" urban environment (which, at the same time, was one of the goals of the authors of the Aspern project). The detailed navigation monostructure 9b is well applicable to the Aspern project, which is capable of creating a spectacular pulsation, compression of space in the direction from the periphery to the central Lake and the main Square of the Aspern. The peculiarity of this mono-Aspern structure is that the fifth color of the elements appears here - yellow. Semantically, this means mixing the adjacent colors on the model and integrating the architectural properties of the building.

It is impossible to see the difference between the "normalized integration" before and after the embedding of navigation structures, since in the computational graph it is practically the same structure. Syntax can only compare the original street network and the part included in the navigation. Art-space sets the semantic properties of landmarks-places in accordance with the modality and the value of their coordinates (Table 2) due to a certain distribution of the architectural properties of paired elements - linear segments and intersection of segments according to the principle of the relationship “background-foreground”.

Table 2: Programming system of semantics of landmarks on the example of the Aspern district project

Elements of navigation monocentric structure (centers, axes, boundaries)	**Coordinates of landmarks-places**		**Verbally distinguishable characteristics of landmarks sites (method: A; B;-A; -B)**						
			Place pattern	**The form**	**Usage**	**Colour**	**Landscape**	**Symbols**	**Visual image**
Borders	Group of landmarks with coordinates 1/2	-+1/2	Crossroads, square	2-11 storey buildings, loggias	Housing, student housing, services	White, gray, red	Paving, greening	Services advertising	 
		+-1/2							
		...							

4 RESULTS

We linked the AS distance intervals with the SS integration intervals to determine the degree of complementarity between the AS and SS methods. Then, the correlation between the weights of the distance indices (0; 1/8; 1/4; 1/2; 1; 2; 4) according to the AS and the weights of the normalized spatial availability according to the SS was estimated. Modelling this problem on the detailed typological structures of the AS according to the assessment of "normalized integration" using the depthmapX program showed:

1. SS gives the maximum values of accessibility (integration) to the main coordinate axes of the AS. Conclusion: CC recognizes the configuration of the coordinate axes of the AC.

2. In navigation structures, boundaries with coordinates 1/2 have the second weight in terms of accessibility. The level of accessibility of the remaining segments-borders decreases in proportion to their metric sizes and distance from the centre (1/4; 1/8). Conclusion: the weight of the boundaries is 1/2; 1/4; 1/8 AC equals CC weight.

3. The outer border has accessibility similar to the inner borders with the distance from the centre 1/4; 1/8. Conclusion: the value of the outer border for AS navigation is higher, than for SS accessibility.

4. In detailed navigation structures, the value of the topological distance of a place is close to its value in terms of normalized integration. Conclusion: SS, like AS, can manage the architecture and semantics of space.

5. The discrepancy between the values of the distance by the AS and the integration by the SS means a decrease in the navigation properties of the structure and turns it into an urban environment or requires the continuation of the detailing of the structure.

6. The art-space methodology is capable of managing normalized accessibility, and the spatial syntax methodology can manage navigation, but does it better with art-space.

5 CONCLUSIONS

This paper discusses the theory we called art-space - a method of forming a spatial navigation structure with given properties in urban design. At the same time, we have shown that the segment analysis of "normalized integration" according to the methodology of spatial syntax adequately reads the navigational and compositional significance of the elements of art-space structures through the significance of segments in terms of accessibility. This will allow, when developing a project for the reconstruction of a city or part of it, first to use the spatial syntax to identify the most accessible paths of movement, and then use them to form the coordinate axes of the navigation structure of the art space. After detailing the navigation structure in the project under development, it is advisable to check its "normalized integration" again. When revealing discrepancies with theoretical navigation structures, different scenarios are possible. 1) Change in the type of navigation structure (base or derivative) with a change in the system of landmarks and functions. 2) Maintaining the structure, but changing functions, including the rank of streets. 3) Not to change anything, realizing that this creates the effect of "unplannedness" of the urban environment with uncertainty during navigation, if this is the purpose of the formed artistic image of the space.

Natural language is a universal communication basis for describing reality and constructing imaginary spaces. Art-space is an artificial graphic language based on natural language. The ontological basis of art-space, as we have shown, is the “three-dimensionality” of mental urban topology, which is fundamentally different from the three-dimensionality of Euclidean space. We declare that when navigating, a person conceptualizes a place as a landmark, if the place is simultaneously semantically defined as a spatial center, a border and an axis-path. This is similar to how the existence of a physical object is proved by the presence of its width, height and depth. Based on this ontology, three types of basic navigation structures were shown with different imaginary artistic spaces and different structural diversity. The navigation structure of the art space in relation to the city as a work of art performs the same function as a frame or linear perspective in a painting. The navigation structure, imposed on the urban environment, only organizes the perception of the subject, indicating the boundaries of the existence of the city-work of art and the possibility of its special "non-utilitarian" cognition. At the same time, the very navigation structure of art-space forms different emotional images of space, depending on the position of the subject inside the city. It can develop and change according to the rules of mutual transformation.

The development of the methodology, both separately for art-space and in conjunction with spatial syntax, requires extensive application practice, including the computerization of graphic 2D and 3D constructions with banks of semantic attributes for modeling spatial landmarks.

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REFERENCES

Al-Sayed, K. et al. (2014) ‘*Space Syntax Method’*. London: Bartlett School of Architecture’, UCL.

Beattie, N. (1990) ‘Imageability and Cultural Identity’. *Culture-Space-History: 11th International Conference of the IAPS.* METU Faculty of Architecture, 8 - 12 July. Ankara: Turkey, pp.113-118

Bellmund, J. et al.(2018) ‘Navigating cognition: Spatial codes for human thinking’. *Science* 2018 Nov 9;362(6415):eaat6766. doi: 10.1126/science.aat6766. PMID: 30409861.

Cauvin, C. (2002) ‘Cognitive and cartographic représentations: towards a comprehensive approach’, *Cybergéo: Revue européenne de géographie,* n° 206, 15/01/2002, 28 p. DOI: 10.4000/cybergeo.194

De Jonge, D. (1962) ‘Images of Urban Areas Their Structure and Psychological Foundations’. *Journal of the American Institute of Planners*, 28(4), pp.266-276.

Fauconnier, G. 1994. ‘*Mental Spaces’*. New York: Cambridge University Press. [Originally published (1985) Cambridge: MIT Press.]

Hartley, T. et al. (2014) *‘Space in the brain: how the hippocampal formation supports spatial cognition’.* Phil. Trans. R. Soc. B 369: 20120510.http://dx.doi.org/10.1098/rstb.2012.051

Herskovits, A. (1986) ‘*Language and spatial cognition: An interdisciplinary study of the prepositions in English’.* Cambridge*:* Cambridge University Press .

Gottdiener, M. and Lagopoulos, A. (1986) ‘*The City and the Sign: An Introduction to Urban Semiotics’*. New York Chichester, West Sussex: Columbia University Press.

Heft, H. (1997). ‘The relevance of Gibson’s ecological approach to perception for environment-behavior studies’. In Moore, G (eds.) *Toward the Integration of Theory, Methods, Research, and Utilization*. AEBD, volume 4. Springer, pp. 71-108:.

Hillier, B. (1996) '*Space is the machine'*. Cambridge: Cambridge University Press.

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

Hillier, B. (1999) 'Centrality as a process: accounting for attraction inequalities in deformed grids'. *Urban design international 4 (3),* pp. 107-127. doi:10.1057/UDI.1999.19

Hillier, B. (2003) 'The architectures of seeing and going: or, are cities shaped by bodies or minds? And is there a syntax of spatial cognition?' *4th International Space Syntax Symposium*. University College London, 17-19 June 2003 : London, UK, pp. 06.1-06.34

Hillier, B. (2009) 'Spatial sustainability in cities: Organic patterns and sustainable forms'. In: Koch, D., Marcus, L. and Steen, J. (eds.), *Seventh International Space Syntax Symposium, Stockholm:* Royal Institute of Technology, pp.K01.1-K01.20.

Hillier, B., Yang, T. and Turner, A. (2012) 'Normalizing least angle choice in Depthmap and how it opens up new perspectives on the global and local analysis of city space' *The Journal of Space Syntax*, volume: 3 issue: 2, pp. 155-193

Hillier, B. (2019) 'Structure or: Does Space Syntax Need to Radically Extend Its Theory of Spatial Configuration?' *12th International Space Syntax Symposium*, Jiaotong University Beijing 8 -13 July 2019, Beijing: China, keynote, pp.1-26

Kolontay, A. (1987) 'Urban project art space. Vytvarny prostor urbanistickeho dila'. *Vystavba a architektura,* Issue *5*, Praha: Czech, pp.17-30(in Czech)

Kolontay, A. (2019) 'Smart and emotional – the city as a work of art'. *24th International Conference on Urban Planning. REAL CORP 2019*. Karlsruhe Institute of Technology, Germany 2-4 April. Vienna: CORP, pp. 949-954.

Kolontay, A. (2020) 'City as a novel' [Lecture] 8TF1GJWdmJY. Institute of the General Plan of Moscow, December 2nd

Kolontay, A. (2021) 'Spatial Navigation Modeling Technology in Urban Planning Project'. *26th International Conference on Urban Planning, Regional Development and Information Society. REAL CORP 2021*. University of Natural Resources and Life Sciences (BOKU) Vienna 7-10 Sept. Vienna: CORP, pp.705-714.

Langacker, R. (1986) 'An Introduction to Cognitive Grammar'. *Cognitive Science, 10 (1)*, pp.1-40. DOI: 10.1207/S15516709COG1001_1

Landau, B. and Jackendorff, R. (1993) '"What" and "where" in spatial language and spatial cognition'. *Behavioral and Brain Sciences,* 16:2, pp. 217-238.

Lefebvre, H. (1991) '*The Production of Space'*. Translated by Donald Nicholson-Smith. Oxford: Blackwell.

Lynch, K. (1960) *'The Image of the City'*. Cambridge MA: MIT Press

Pafka, E. (2017) 'Integration is not Walkability: The limits of axial topological analysis at neighbourhood scale'.*11th Space Syntax Symposium*. Instituto Superior Técnico Lisbon 3-7 July . Lisbon: Portugal, pp.102.1-102.10.

Penn, A. (2003) 'Space Syntax and Spatial Cognition: or, why the axial line?' *Environment and behavior 35 (1),* pp. 30-65

Ratti, C. (2004) 'Space syntax: some inconsistencies'. *Environment and Planning B: Planning and Design 31*(4), pp. 487-499.

Rauschenbach, B. (1986) '*Perspective systems in the visual arts. General perspective theory'*. Moscow: NAUKA (in Russian)

Siegel, A. & White, S. (1975) 'The development of spatial representations of large scale environments'. In: Reese H (ed*) Advances in child development and behaviour* 10. Academic, New York, pp 9-55

Stahle, A. et al. (2005) 'Place Syntax - Geographic Accessibility with Axial Lines in GIS'. *5th international space syntax symposium*, Delft, Netherlands 13-17 June, pp. 131-144.

Talmy, L. (1983) 'How language structures space'. In: H. L. Pick, Jr. & L. P. Acredolo (eds.): *Spatial orientation: Theory, research and application. Plenum*, NY, pp. 225-282.

Toporov, V. (1983) 'Space and text'. In: *Text: semantics and structure*. Moscow: NAUKA, pp. 227-254 (in Russian)

Tversky, B. (1993) 'Cognitive maps, cognitive collages, and spatial mental models'. In: Frank A.U., Campari I. (eds) *Spatial Information Theory A Theoretical Basis for GIS.* COSIT 1993. Lecture Notes in Computer Science, vol 716. Springer, Berlin, Heidelberg, pp. 14-24

Tversky B.(2019) *'Mind in Motion: How Action Shapes Thought'*. New York, N.Y: Basic Books

Tversky, B., & Lee, P. (1998). 'How space structures language'. In C. Freksa, C. Habel, & K. F. Wender (Eds.), *Spatial cognition: An interdisciplinary approach to representation and processing of spatial knowledge*, Hamburg: Springer, pp. 157-175