Alternative Geometry for Space Syntax

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Abstract
'Space syntax' introduced by Hillier and Hanson refers to a set of techniques by which topological space structure of a built environment is described and different topological space structures are compared. At a more abstract and theoretical level, they argued that the topological space structure of a built environment should be an autonomous social variable rather than a determinative subservience to other variables. Here we are interested particularly in the methodology of describing the topological space structure of a built environment.

Topological space structure is normally depicted in such a way that a node indicates a space while a link indicates physical accessibility between spaces. It is apparent that the identification of a space unit must be made before physical accessibility between space units is determined. Thus, there must first be a method of identifying 'space cells' in a built environment in order to describe the built environment in terms of topological space structure. In other words, describing topological space structure hinges on a comprehensive method of identifying space units in a built environment. If the space units of a built environment are not identified in a commonly agreeable manner, it is always possible to question the validity of comparing built environments in terms of their underlying topological space structures.

Architectural space can be distinguished as a perceptual primitive, not as a conceptual element. In other words, a space in a plan can be identified as an atomic region by shape information alone without any associative intervention of additional semantic knowledge such as use, material construct, meaning, familiar cultural settings, etc. Two things must be noted in relation to the meaning of architectural space. First, a space is not a transient entity as its boundary changes according to the movement of an observer. Second, a space differs from a room as it is fully circumscribed by wall surfaces. And a room can be a composite of spaces.

The question of objective space identification is a very important point because if spaces are not identified in a very disciplined manner in the first place, their subsequent space organization is not an objective description but a mere subjective interpretation. In this paper, I first formulate the problem of identifying perceptual space units in 'convex break-up' technique in a methodological point of view. And I attempt to solve the problem of identifying morphological space primitives by introducing the concept of the field of 'enclosing balance' and I also propose 'primitive balloon representation' as an alternative geometry for space syntax. Next I will demonstrate the robustness of my space identification technique and also discuss its limits and implications.

1. Introduction

This research started from my simple intuitive conviction that a space in a plan can be distinguished as a perceptual primitive, not as a conceptual element.[1] In other words, a space in a plan can be identified as an atomic region by shape information alone without any associative intervention of additional semantic knowledge such as use, material construct, meaning, familiar cultural settings, etc. The comparison between primitive identification in shape representation and element identification in map making may clarify the distinction between 'perceptual primitive' and 'conceptual element.'

In map making, it is presupposed that there are different types of physical elements. However, physical elements of a map cannot be identified solely by shape information alone. For example, the identification of map elements is hardly possible from a satellite photograph if one is not familiar with the environment of the satellite photograph. The main point here is that element identification in map making is driven by previously acquired semantic knowledge and not by the differences of shape information alone. In this sense, a map element is a conceptual element. In contrast, the perceptual primitives have to be derived from received shape information alone. A space primitive of a plan is a perceptual entity in the sense that its identification depends solely upon received shape information without the intervention of acquired semantic knowledge.

Two things must be noted in relation to the meaning of architectural space in a plan. First, a space is not a transient entity as its boundary changes according to the movement of an observer. A space is a permanent entity in the sense that it is defined by the relation between a void and its enclosing solid. Second, a space differs from a room in a plan. A room is fully circumscribed by wall surfaces. On the contrary, a space is identified as such when it is sufficiently 'enclosed' by wall surfaces. A room can be a composite of spaces.

The question of objective space identification in architectural plan is a very important point because if spaces are not identified in a disciplined manner in the first place, their subsequent space organization is not an objective description but a mere subjective interpretation. Therefore, without providing a commonly acceptable technique for identifying morphological primitives of architectural space, those who pursue space organization for a wider audience have to bear the burden of subjectivity. This question is very puzzling because it is essentially connected to the question of shape recognition.

In this paper, I first reveal the inherent problem of 'convex break-up'technique which was introduced as a method of segmenting perceptual space units in a built environment, in the methodological sense that the technique leads to multiple descriptions of a complex planar shape. Secondly, I attempt to solve the problem of identifying morphological space primitives by introducing the concept of the field of 'enclosing balance'. And I propose 'primitive balloon representation' as an alternative geometry for space syntax which necessarily leads to a unique description of a complex planar shape and I also demonstrate methodological robustness of my space identification technique by the application of my software program to exemplary cases. Lastly, I will discuss the limits of my space identification technique and the direction of future research.

2. Problem Formulation

Hillier and Hanson introduced 'space syntax' to refers to a set of techniques by which topological space structure of a built environment is described and different topological space structures are compared.[2] They proposed a methodology for describing topological space structure of a built environment. At a more abstract and theoretical level, they argued that the topological space structure of a built environment should be an autonomous social variable rather than a determinative subservience to other variables. Here we are interested particularly in the methodology of describing the topological space structure of a built environment.

Topological space structure is normally depicted in such a way that a node indicates a space while a link indicates physical accessibility between spaces. It is apparent that the identification of a space unit must be made before physical accessibility between space units is determined. Thus, there must first be a method of identifying 'space cells' in a built environment in order to describe the built environment in terms of topological space structure. In other words, describing topological space structure hinges on a comprehensive method of identifying space units in a built environment. If the space units of a built environment are not identified in a commonly agreeable manner, it is always possible to question the validity of comparing built environments in terms of their underlying topological space structures.

Hillier and Hanson took it for granted that interior space identification can be made without ambiguity. Although they did not specify explicitly how to identify interior spaces, they use two different methods of identifying them. One is to identify an interior space unit by its specific use.[3] In this case, interior space units are defined as 'conceptual elements' because they are identified in terms of semantic knowledge such as specific use, control gates and other physical cues. It seems very reasonable to identify an interior space unit in terms of its specific use, especially when seeking the actual social pattern of an existing built environment.

The other method is to rely on our intuitive perceptual ability to distinguish interior space units in terms of shape information alone. Space recognition in the plans of Figure-1 may seem obvious intuitively. One may think that the key determinant of identifying space units is the existence of an opening between two protruding wall ends. However, one may soon notice that the alignment of two protruding wall ends may not be enough to determine the existence of an opening if the distance between those two wall ends is too large. Note that the opening between area-6 and 4 in plan (c) of Figure-1 looks very different from the others. It is also a robust perceptual fact that one protruding wall can make an opening if opening width is narrow enough. Thus, it is wrong to assume that the existence of an opening is determined only by the alignment of two protruding wall ends.

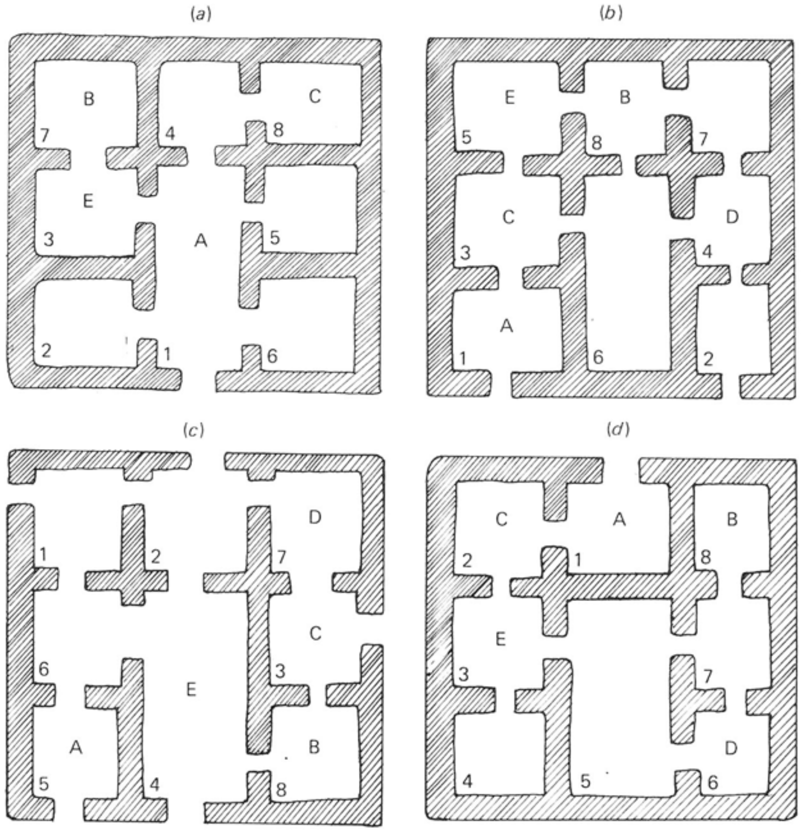

Figure 1
Four theoretical building plans (from The Social Logic of Space, p. 150)

It seems obvious that not particular wall elements and their dimensions but the whole surroundings are responsible for the perception of an opening. I would argue that the experiential concept of an opening cannot be explained coherently and comprehensively in terms of particular wall elements and their dimensions. My point here is that interior space identification is the heart of the problem which cannot be avoided if one wants to describe relations between interior spaces.

Hillier and Hanson did not employ the latter intuitive method of interior space identification for describing topological space structure of a built environment although they implicitly used it for four hypothetical plans of Figure-1.[4] However, as for continuous open space which refers to the outdoor space between buildings and houses, the inherent problem of space identification is pertinent because space units cannot be identified in outdoor open space in terms of specific use and control gates. Thus, Hillier and Hanson specified a method of identifying space units in outdoor open space.[5] They wrote,

"In fact it is quite easy to make a convex map. Simply find the largest convex space and draw it in, then the next largest, and so on until all the space is accounted for. If visual distinctions are difficult, then the convex spaces may be defined in two stages; first, by using a circle template to find where the largest circles can be drawn in the y-space, and second, by breaking the convexity rule and without reducing the fatness of any other space."[6]

The first method specified in the above quote does not have any substantial content because the task of space identification is to specify what they mean by 'visual distinctions'. The second method also fails to deliver the specification of space identification simply because a coherent and complete procedure of segmenting space units cannot be derived from their statement. Let me take the area around point-A in Figure-2(a) to illustrate the incoherence imbedded in the second method.

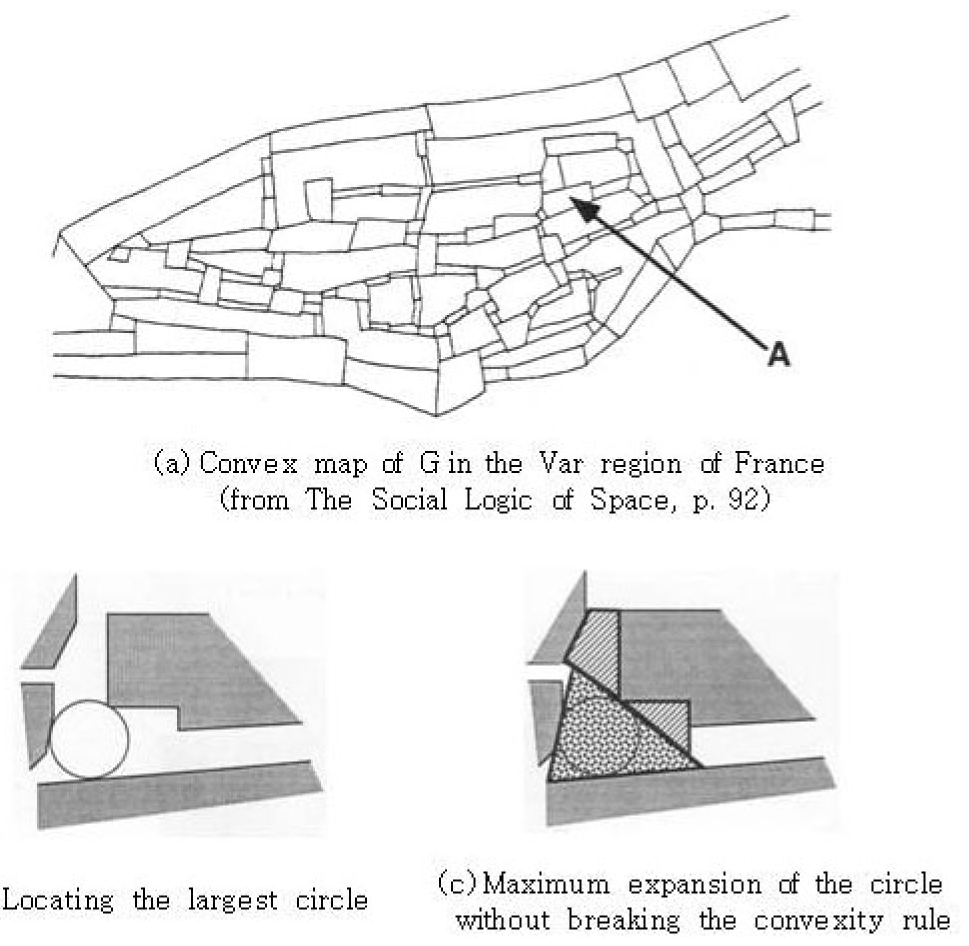

Figure-2
The procedures of deriving convex map

Locating the largest circle into a plan may not be easy but is possible. The largest circle should be at the corner as shown in Figure-2(b). The next step is to expand as large as possible without breaking the convexity rule and without reducing the fatness of any other space. Note that the second conditional phrase is irrelevant because no other space is yet identified. If the second conditional phrase is interpreted as nuisance to be disregarded, the triangle which subsumes the circle is first segmented, and successive segmentation leads to the space identification as shown in Figure-2(c). It is evident that this interpretation is wrong because Hillier and Hanson's exemplary convex map of Figure-2(a) does not comply with the procedure specified in the above.

This naturally forces me to another controversial interpretation of which primary goal is to make sense of their exemplary convex map. My second interpretation is as follows. In the second step of expanding the circle, we can also make the circle shrink if necessary. The conditional phrase of 'without reducing the fatness of any other space' can be made sense only if we change it into 'without reducing the fatness of any other *adjacent space to be*'.

In consideration of their exemplary convex map, it is obvious that my second interpretation is Hillier and Hanson's specification of space identification. Aside from the far-fetched nature of my second interpretation, this method of space identification is incomplete. In order to derive a convex map which should have the least set of fattest spaces, one first has to define the fatness of a space. And then the priority relations between fatness, area, and the number of spaces have to be specified in order to construct any meaningful procedure of space identification. Hillier and Hanson did not specify any of them.

My point here is first that Hillier and Hansoni's procedural specification of 'convex break-up' technique is not concrete and insufficient. And it is simply wrong to posit a 'convex map' of Figure-2(a) as the result of representing space segmentation through a consistent algorithm rather than an intuitive interpretation. Second, 'convex break-up' method is inherently deficient because it cannot necessarily lead to a unique description of a complex space shape due to the incommensurability between conflicting factors as I demonstrated in Figure 2-(c). In order to settle this problem of space identification, the idea of the field of i'enclosing balance' is formulated as an alternative algorithm and the concept of primitive balloon representation is constituted as an alternative geometry for space syntax.

3. Transform Algorithm of Enclosing Balance

The idea of 'enclosing balance(EB)' starts from the premise that an observer can sense the 'directional inclination' at each void point on an architectural plan through the imaginary visual perception of the enclosing solid wall surfaces. When a person projects himself into an architectural plan in order to visually perceive the imaginary environment that the plan projects, the point of observation from which he chooses to look around is the void point. Any location in the empty space area of an architectural plan can be a void point. Solid points refer to the wall surfaces of solid material which are normally indicated by the black marks on an architectural plan. What bounds the lines of sight radiating from a void point are the wall surfaces which enclose the void point directly. Only those enclosing surfaces should be responsible for the perception of the directional inclination at the corresponding void point. The enclosing wall surfaces can be represented by the collection of the solid points which constitute those surfaces as shown in Figure-3(a). It seems fair to say that the idea of directional inclination originates from the architect's location-centric perception of plan drawing.

The EB is distinct from directional inclination in the following sense. The EB denotes a quantitative measure which is objectively calculated at each void point in an imaginary physical environment. The directional inclination denotes the visual perception which I assume is caused by the EB. In other words, the EB is an imaginary stimulus and the directional inclination is the response to that stimulus. The idea of positing the EB as physical information distinguished from the psychological information of directional inclination is based upon the simple notion which underlies the psychophysical method, that is, perceptual response arises from physical stimulus.[7]

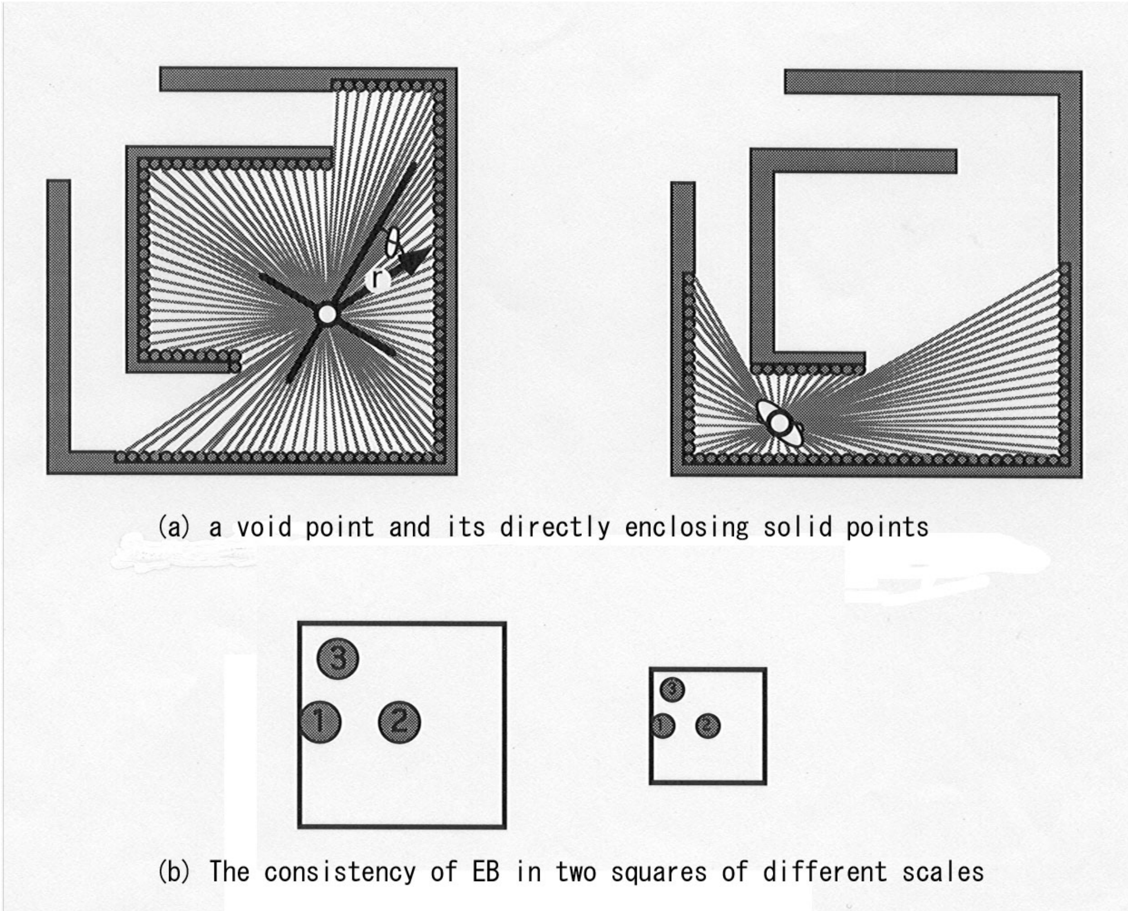

Figure3
Theoretical formulation of enclosing balance

In normal perceptual use of the psychophysical method, a stimulus is specified and assumed to be directly perceived. The purpose of psychophysical investigation is to understand how a change in the stimulus affects our perception of the stimulus. On the contrary, in the relation between EB and directional inclination, what is known are the variables by which a stimulus is formulated but not the stimulus itself; the stimulus is assumed to be perceived indirectly through the imagination. The purpose of our investigation is to infer, by combining given variables, a plausible underlying algorithm for constructing the stimulus in consideration of some commonly shared samples of imaginary perceptual experiences, that is, directional inclination.

The EB should be constructed in compliance with directional inclination. Nevertheless, the algorithm of EB, once formulated, is independent of directional inclination in the sense that the EB can always be used as an explicit tool of characterizing the void point because the variables of EB algorithm are physical properties. The important point here is that the algorithm of EB, as an explicit tool for characterizing each void point on an architectural plan, is independent of visual information processing.

As the term EB is composed of the two words 'enclosing' and 'balance', the meaning of each word contributes to the idea of EB. The EB at a void point is determined by the solid points which enclose that void point directly. The directional inclination disappears at the location of 'centered symmetry' because the enclosing environment is entirely balanced at that center point. In other words, the magnitude of the EB at this balanced point must be zero. At the other void points, an observer feels inclined to a certain degree in a certain direction because the enclosing environment is unbalanced as such. The EB at a void point is normally the resultant vector determined by the directly enclosing solid points of the void point.

This idea of EB is systematized by analogy with gravitational force. The analogy is such that a solid point radiates 'visual influence' into the area of void points like a unit of mass radiates gravitational force into the space. However, the visual influence does not penetrate through the solid point in the way while the ray of gravitational force does penetrate the mass in the way. The ray of visual influence simply dies out when it hits a solid point. It must be also noted that the ray of visual influence carries two kinds of influence at the same time. One is the 'vector visual influence' (VVI) and the other is the 'scalar visual influence' (SVI). Both VVI and SVI converge into a void point in all ambient directions. The 'total vector visual influence' (TVVI) refers to the vector addition of all VVIs which converge into a void point in all ambient directions. And the 'total scalar visual influence' (TSVI) refers to the addition of all SVIs which converge into a void point in all ambient directions. The EB at a void point is defined as the division of TVVI by TSVI.

EB is defined to sustain the consistency of EB in the same shape. In other words, the EB is formulated to be independent of scale changes in a shape as shown in Figure-3(b). An additional elegance achieved from dividing TVVI by TSVI is that the magnitude of EB is always between 0 and 1. The EB at a void point is expressed in mathematical terms as follow.

$$EB = \frac{\int_0^{2\pi} \overline{r(\theta)} / r(\theta)^2 \cdot \partial\theta}{\int_0^{2\pi} 1 / r(\theta)^2 \cdot \partial\theta} \quad r = \text{the distance from a void point to each solid point}$$

4. Primitive Balloon Representation

The magnitude surface of the field of EB (FEB surface) can be drawn by level lines, each of which is a line of the same magnitude of EB. By observing the FEB surfaces of the three probative shapes as shown in Figure-4, one may easily notice that the competence of FEB surface for part decomposition is self-explanatory in the topography of FEB surface. The FEB surface of each probative shape is a topography which consists of two different basins connected through a canyon. The smaller basin is shallower in the sense that the EB height at its lowest point is not zero but stays around 0.15. On the contrary, the larger basin is deeper because the EB height at its lowest point is near zero. The canyon between two basins has a hill with a height of around 0.3. Local basins of FEB surface can be used as a natural determinant of part identification. It is obvious that the part decomposition which is suggested by local basins of FEB surface accords with our visual cognition of space regions in the same shape plan. The FEB surface is invented to provide a platform of commensurable measure from which an acceptable standard of identifying space primitives in a plan can be determined.

A space primitive of a plan is commonly identified in a plan not by complete enclosure of wall surface. When an area is perceived as a space in a plan, the area need not be fully enclosed by wall surface. The point here is that full enclosure, that is, explicit space boundary is not a determinant of identifying a space primitive in a plan. The critical observation is that a space primitive is distinguished rather than segmented in a plan. When an area is perceived as space primitive, the boundary line of the space is ambiguous. A Space primitive is distinctive not in the sense that it is cut off by explicit boundary edges but rather in the sense that the central area of a space primitive is somehow identifiable against its periphery.

There are two different ways of identifying space primitives from an FEB surface. One way is to make the boundary edge explicit by using the line of watershed. This may be a natural method if the purpose is to segment topographic surfaces into divided pieces. If one considers a FEB surface as land topography, then the task is to figure out the system of drainage basin. A depressed area which holds drained water stagnant may be defined as a basin of space primitive. The segmenting line of a watershed can be uniquely drawn on a FEB surface without any additional constraint. The other way is to make explicit the basin core around the nadir by slicing the FEB surface horizontally. Of course, the identification of space primitive depends on the EB height of a horizontal slice which has to be determined. This is a sufficient method if the purpose is not to segment the surface but to identify space primitives, that is, determining the existence of space primitives.

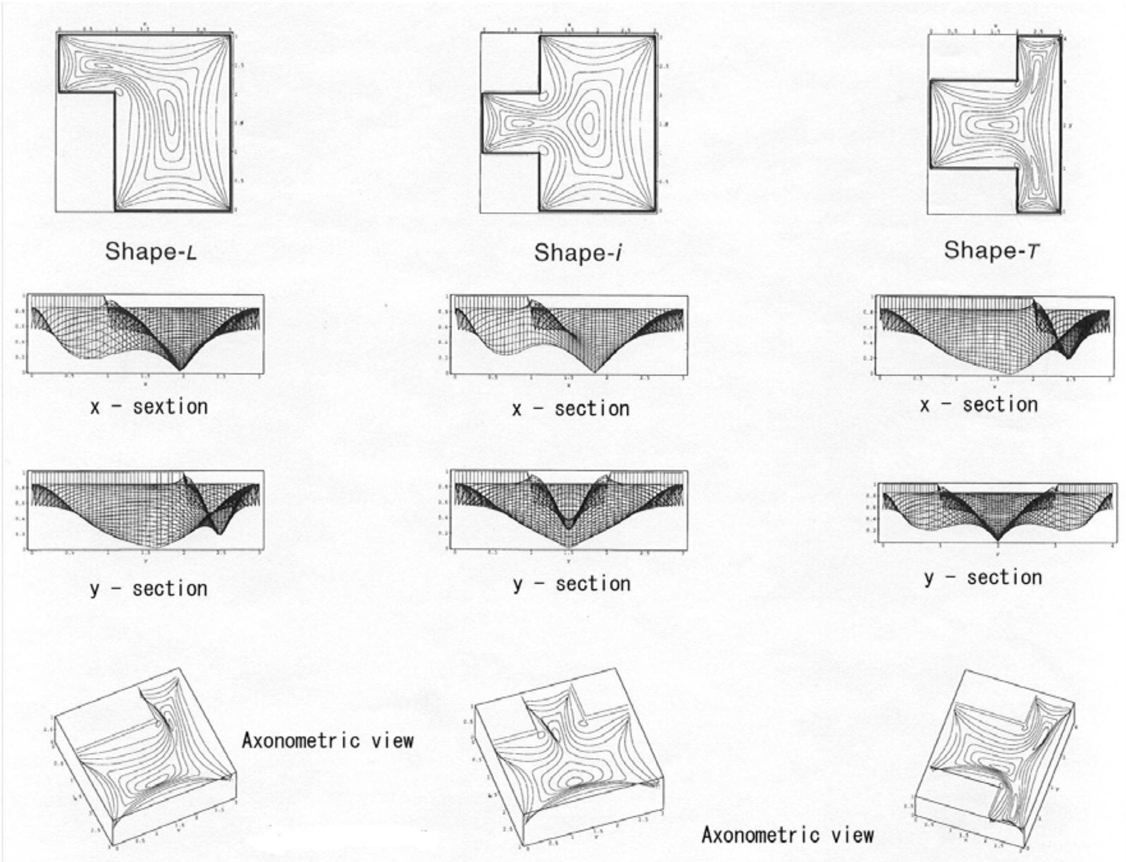

Figure 4
The FEB surfaces of three probative planar shapes

The method of using the segmenting line of watersheds to identify space primitives has to be rejected because space primitive is distinguished not by a sharp boundary edge but by a nebulous central core. The fundamental essence of this argument is that the planar shape of a plan should be described by two alternative ways which complement each other. One is in terms of the line composition of exact wall surfaces and the other is in terms of area arrangement of nebulous space units.

The EB height of the horizontal slice which identifies basin cores on FEB surface can be determined either relatively by a median value between basin nadir and canyon top or absolutely by a definite value. After careful investigation of the FEB surfaces of various corridor bends and junctions such as angle-shape, ㄷ-shape ㅏ-shape, †-shape, 0.18 EB is tentatively designated as a definite value whose horizontal plane slices basin cores from FEB surface.

The idea of describing space primitives from FEB surface is a two-step procedure. First, the existence of a space primitive is determined by its basin core. Second, the space primitive is described by extending its basin core outwards up to the boundary. Because a FEB surface is continuous and smooth, it seems possible to draw the extrapolation algorithm which naturally extends the basin core outward up to its boundary. However, the boundary of a space primitive is ambiguous and blurred by definition. Thus, a rough proportional approximation of horizontal extension may suffice to describe a space primitive.

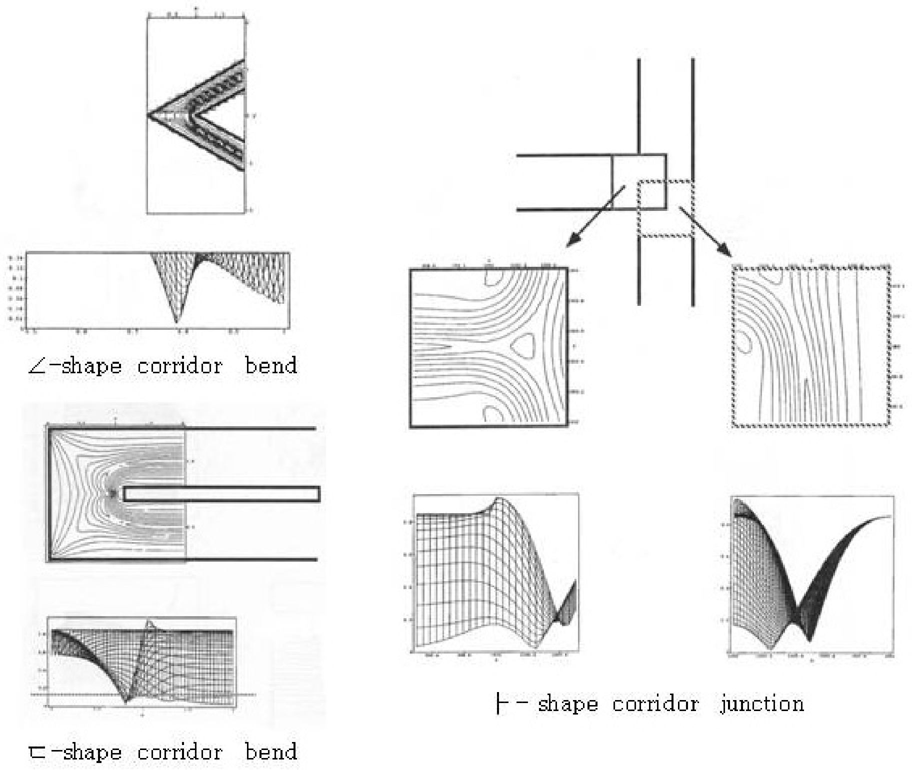

Figure 5
FEB surface analysis of corridor bends and junction

Primitive balloon representation is named after the process of extending the basin core outward which resembles the process of inflating a balloon. The underlying connotation is that as the original balloon rubber has the seed of the inflated balloon, an area primitive has to be derived from a basin core which is the seed of a planar shape.

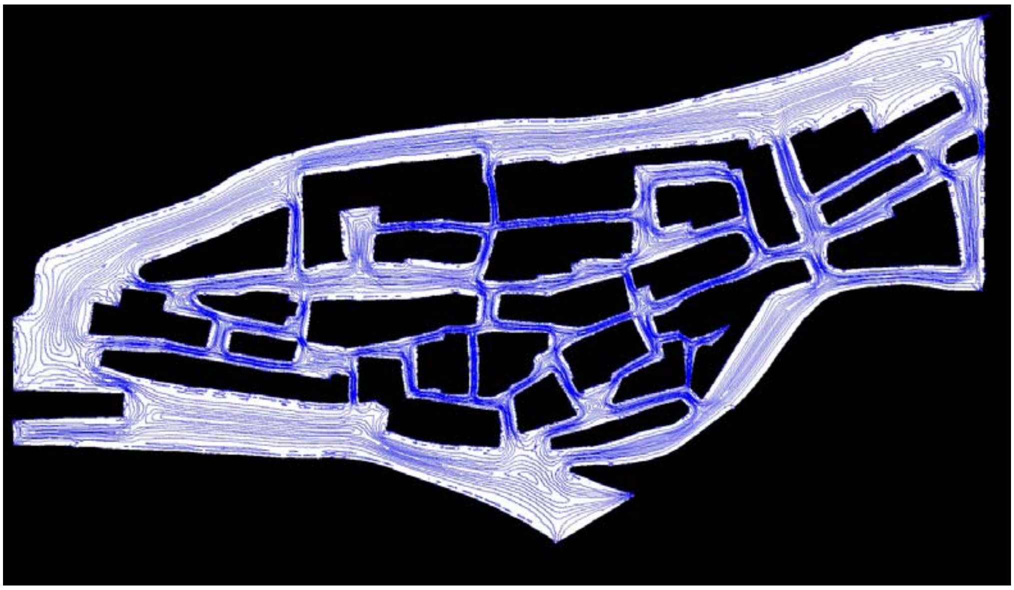

Figure 6
Contour-lined FEB surface of 0.1 EB intervals

Transform algorithm of EB is implemented into a software program of FEB surface.[8] In order to demonstrate the robustness of my space identification technique, Hillier's town of G is selected as an exemplary case for its application. The following three figures are resulted from the application of my FEB surface program to town plan of G. Figure-6 shows the contour lines of 0.1 EB intervals on the FEB surface of town G. The basin cores of tentative space primitives are segregated from the FEB surface in Figure-7 by a definite value of 0.18 EB. The arrangement of space primitives are drawn manually in Figure-8, based upon the basin cores identified in Figure-7.

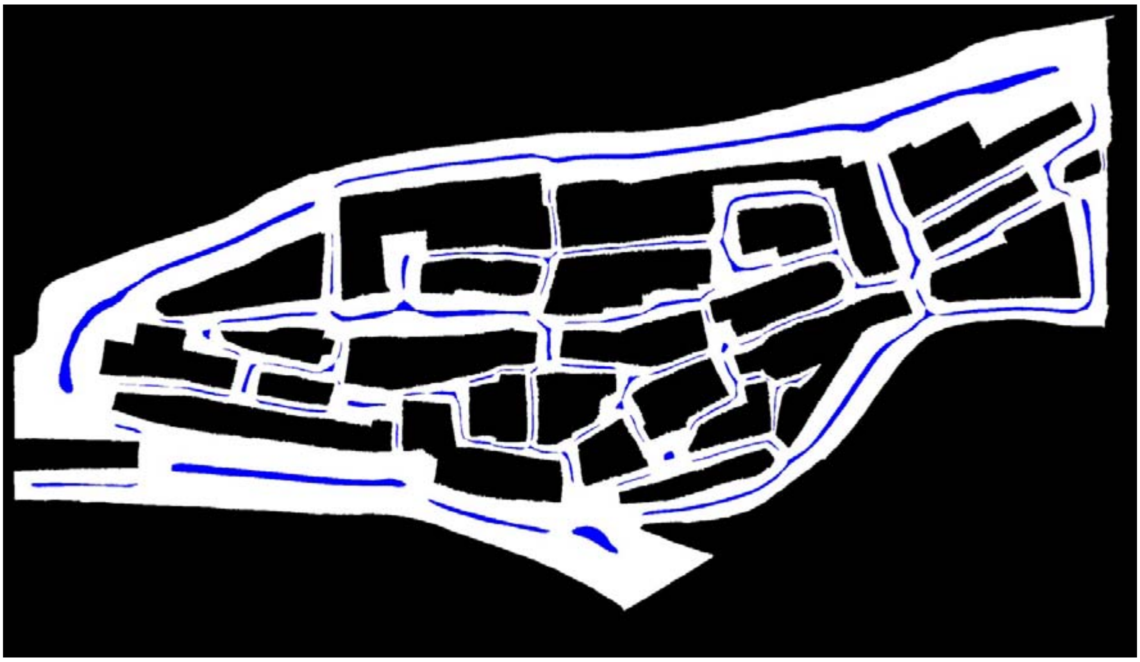

Figure 7
Basin cores segregated by a definite value of 0.18 EB height

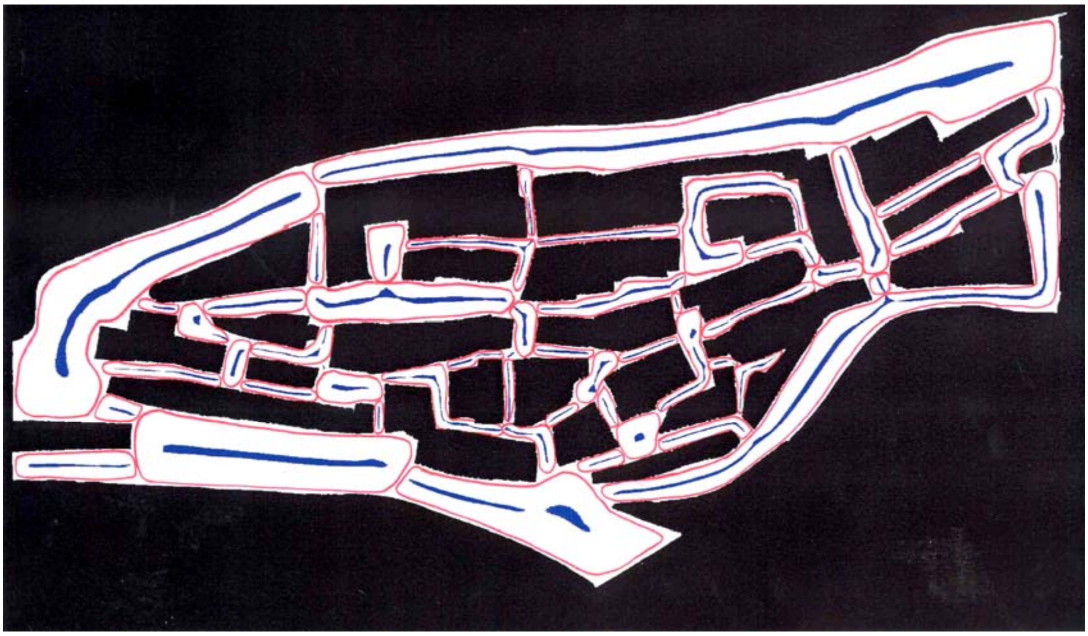

Figure 8
Space arrangement of town G, derived through primitive balloon representation

5. Discussions

It must be noted that my characterization of space primitives of a plan may not be agreed upon universally. One may consider that full enclosure should be the determinant of identifying space primitives in a plan due to the importance of control gates in physical accessibility. Another person may consider that convexity should be the determinant of identifying space primitives in a plan due to the importance of direct visual accessibility. One may oppose my characterization of space primitives because they are identified in a scale-independent condition. He may argue that architectural space cannot be perceived without the association of human scale. Of course, each argument has its basis. Nevertheless, my characterization of a space primitive has its point.

From a purely methodological viewpoint, the method of using a mid-height between basin nadir and canyon top is superior to the method of using a definite EB height due to the following two respects. First, the latter method requires additional constraints in order to determine a definite EB height. Different EB heights may result in different identifications of space primitives. On the contrary, the former method does not require any additional constraints and the identification of space primitives is unique. Second, the former method subsumes the latter method in the sense that the space primitives identified by the former method can always be described as a composition of the space primitives identified by the latter method but not vice versa.

Further studies on the FEB surfaces of various plans may be needed in order to search for a universally agreeable method of identifying space primitives in terms of basin cores as well as to fully understand the characteristics of FEB surface. However, it seems already clear that space primitives identified in terms of FEB surface information must be very different from the shape categories of Euclidean geometry because space shapes are described not in terms of boundary lines but in terms of internal area. It must be noted that the identification of space primitives is a necessary step in describing a plan in terms of topological space structure.[9]

Notes

1 The comparison is postulated because map and plan has to be represented somehow in our cognitive mind. It may be worth nothing that the underlying intention is to compare my morphological space primitives with Lynch's five cognitive map elements. See *The Image of the City* by Kevin Lynch (1960).

2 See *The Social Logic of Space*, by Bill Hillier and Julienne Hanson (1988), Hillier et al., (1987), and Hillier et al. (1983).

3 As far as I know, Hillier and Hanson used this method to analyze topological space structure of a built environment such as farm houses in Normandy, and some English houses and two large African ethnographic complexes. See Hillier and Hanson (1984), 155 and 175, and Hillier et al (1987), .363-385.

4 I can certainly agree to the robust fact that eight space units are perceived in each plan of Figure-1 despite the ambiguity of the openings in plan (c). However, it must also be noted that deliberate efforts are made to make those plans look casually drawn. It is a rare case in which the determinant of identifying space units can be specified in clear terms. Unfortunately, the simplification seems to disguise the sheer difficulties of space identification.

5 Hillier and Hanson asserted that two different ways of describing outdoor open space are possible. One is by defining 'stringiness' as being to do with the extension of space in one dimension and the other is by defining 'beadiness' as being to do with the extension of space in two dimensions. The resulting diagram of the former method is named as 'axial map' while that of the latter method is named as 'convex map'. I am here concerning only with the latter method of describing outdoor open space because I am interested in describing space unit as two dimensional area in a plan, not one dimensional line. See Hillier and Hanson (1984), .90-92.

6 Hillier and Hanson (1984), p.98

7 The psychophysical method originated from studies investigating the relation between properties of physical stimulus and 'sensory' response to that stimulus. Because physical science permits accurate measurements on a physical scale of the magnitude of a stimulus, it is possible to catalogue the difference in sensation, that is the different experiences that we can distinguish within each sensory modality. However, the psychophysical method is used to

measure not just sensitivity but 'perceptual' responses arising from stimuli. It is in this perceptual use of the psychophysical method that the relation between EB and directional inclination is to be understood. For further information, refer to Perception, by J. Hochberg, 1976, pp.13-20 and "Psychophysics and the concept of the threshold", in Theories of Visual Perception, by I. Gordon, 2004.

8 A computer software program of FEB surface is developed with C++ language to be run in normal PC. The FEB surfaces shown in this paper are mostly the results derived from this computer program.

9 Acknowledgement : This work was supported by the Korea Research Foundation Grant funded by the Korean Government (KRF-2008-314-D00445).

References

Lynch, Kevin. 1960. *The Image of the City*. MIT Press.

Hillier, Bill and Julienne Hanson. 1984. *The Social Logic of Space*.

Hillier, Bill et al. 1987. Ideas are in things: an application of the space syntax method to discovering house genotypes. *Environment and Planning B: Planning and Design*, volume 14, 363-385.

Hillier, Bill, et al. 1983. Space Syntax: A different Urban Perspective. *Architectural Journal* no. 30.

Hochberg, J. 1976. *Perception*.

Hochberg, J. 2004. Psychophysics and the concept of the threshold. In *Theories of Visual Perception*, by I. Gordon.