Geometries of Architectural Description:
shape and spatial configuation

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Dr John Peponis
Georgia Institute of Technology, United States of America

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Dr John Peponis
College of Architecture
Georgia Institute of Technology
Atlanta, Georgia, 30332-0155, United States
tel: (1) 404 894 7667
fax: (1) 404 894 1629
e-mail: john.peponis@arch.gatech.edu

0 Abstract
Built shape, initially defined as a finite set of positioned wall surfaces, is described in relation to spatial configuration, defined as the underlying structure of potential movements. Spatial configuration is analyzed by reducing the infinite number of points that can be occupied by a moving subject, into a finite number of discrete convex areas, each of which is stable with respect to the visual information about shape that is available from inside it. Shape is reconstructed by showing how itselements can be coordinated into a smaller number of sub-shapes based on its relation to spatial configuration. "Space syntax" is treated as a geometry for the description of architectural space from the point of view of its configurational properties which are particularly relevant to the social function and cultural meaning of layouts. The aim is to complement "space syntax" by contributing a theory of the intelligibility of shape and spatial configuration which operates not so much at the level of graph theoretical measures, but rather at the level of the recognition of elements and relationships that is a prerequisite for any graph-theoretic analysis.

1 Defining shape and spatial configuration

This is a summary of a presentation regarding the description of built shape and spatial configuration. Only built shapes not involving curves are considered and the discussion is limited to plans. The term “built shape” is used to refer to the set of all wall surfaces of a complex. Surfaces are held to extend between free standing edges and/or corners and not to intersect other surfaces except at their perimeter. Walls can be represented as one dimensional lines with two sides, distinguished according to the corresponding division of space. The term spatial configuration is used to refer to the structure of potential movement and copresence as determined by the placement of boundaries in space and by the connections and disconnections between areas that results from the presence of boundaries. This definition is further clarified in section 3 below.

2 Towards a reconstruction of shape from the point of view of the moving subject

The main point of the presentation can be introduced as follows. Traditionally, shape has been defined constructively. The simplest way to explain what I mean by the constructive definition of shape is this: Imagine that you are about to copy a shape in plan. The simplest procedure is to copy each surface by determining the position of its defining discontinuities so as to be able to draw a line between them. Sometimes, however, the placement of the next surface can be determined from the position and relationships of surfaces already drawn, by using the drawing instruments and by applying geometrical knowledge. Indeed, the constructibility of figures by means of operations involving a limited set of drawing tools, has been a topic of geometrical investigation from Euclid (1956) to Hilbert (1971). The more we can derive the entire shape from a few elements initially positioned, the more we can argue that the shape has a coherent structure, in other words, that the placement of one element has logical consequences for the placement of others. This is often fundamental to architects, not merely as a matter of technicality, but as a dimension of architectural meaning which is inherent in the form. The obvious and familiar problem with such definitions of shape is that they suppose a panoramic apprehension of all relationships involved. Since buildings are subdivided and can never be seen entirely from any single point, such apprehension is only possible by studying representations such as plans and sections, and by reconstructing the form not as an image that corresponds to a viewing point, but rather as an abstract schema in the mind. Thus, the traditional constructive definition of shape does not seem to engage the experience of architecture by the moving subject. I want to suggest some steps that may bring us closer to the development of constructive descriptions of shape from the point of view of a moving subject . The key is to show how partial information that is directly seen can be coordinated into more complex patterns. I use the term coordination in the way in which it is used by Piaget (1967), to refer to the establishment of complex patterns of relationships on the basis of operations that can be repeated and reversed.

3 "Space syntax" is an architectural geometry

Before all else, clarifications are in order as to how such argument features in a discussion of "space syntax". Hillier and Leaman (1975) and Hillier et al (1976) use the term "syntax" to refer to rules that account for the generation of elementary, but fundamentally different, spatial arrangements. Hillier and Hanson (1984) define syntaxes as combinatorial structures which order the world and also allow us to retrieve descriptions of it. Consistent with the above publications, they propose that there is a relationship between the generators of form and social forces. However, they then proceed to develop techniques of syntactic analysis which can be applied to settlements and buildings treated as individuals and not merely as members of generative classes. This opens the way for subsequent definitions of the terms "space syntax". Hillier et al (1983) and Hillier et al (1987) define "space syntax" as a methodology, or a set of techniques for the representation, quantification, and interpretation of spatial configuration in buildings and settlements. Hillier (1996) shows how the key configurational properties represented and analyzed by syntax, interact with configurational rules, for example those affecting the shape of the perimeter of a cell or the positioning of partitions inside it.

Quite clearly, the methodology has to be distinguished from the substantive theories regarding the social functions and cultural meaning of built space advanced by Hillier, Hanson or others. And while in the earlier work the formulation of generative principles was seen as a priority, we must now acknowledge that potential generative principles are investigated more from the point of view of their effects and less from the point of view of their own structure. They are studied from the point of view of their implications concerning those properties of arrangement that the analytical methodologies have brought to the fore. Where does all this leave us, regarding the definition of what we mean by "space syntax"? To say that "space syntax" is merely a set of techniques does not do justice to the work. In so far as space syntax has defined spatial configuration in terms of some tangible properties of arrangements, it is certainly a theory of architectural geometry, or can be developed more firmly in that direction. Here, we interpret “geometry” in a broad manner, to denote any theoretical account of the formal structure of the built environment, following the usage of March and Steadman (1971). Space syntax allows us to understand and describe built space as a field of potential movement and copresence. The very definition of spatial configuration proposed above assumes precise analytical and theoretical significance thanks to “space syntax”. The description of spatial configuration requires us to look at the movement sequences, changes of direction, intersections between different directions, the presence of alternative sequences linking the same two areas, the occurrence of centers of convergence or domains of exclusion, and so on. “Space syntax” has made this possible in three essential steps: first, spatial patterns are represented as sets of linear elements of potential movement or convex elements of potential togetherness. Second, systems of relationships are described according to the permeable adjacencies of convex spaces, the overlap of convex elements, or the intersections of lines -linking elements according to the intersections of their “isovist” has also been practice, following an adaptation of Benedikt’s (1979) ideas. Third, graph-theoretic measures, such as “connectivity”, “integration”, “intelligibility”, and “choice” are applied to the systems of relationships thus established.

4 Interaction and independence of shape and spatial configuration

“Space syntax” has not traditionally sought to be “shape-discriminating”, as indicated by the fact that the shape of the perimeter of convex spaces, or the form and alignment of built edges at either side of an axial line, are not specifically taken into consideration. The partial disregard of shape can to some extent be traced to the idea that the level of spatial description that is relevant to analyses of the social functions and cultural meanings of layouts is closer to the topological than to the metric (Hillier and Hanson, 1984). At the same time, “space syntax” has not traditionally been “shape-blind”. Syntactic descriptions distinguish between arrangements that are topologically equivalent. Syntactic representations, contingent as the are upon whether an axial line or a convex space can be extended, are quite evidently constrained by shape. More recently, Hillier (1996) has sought to bring shape into the purview of the graph-theoretic measures of “space syntax” by redefining elements so as to include not only convex spaces and axial lines, but also an underlying two dimensional orthogonal metric. His underlying aim seems to be to develop a framework that allows us to handle metric and topological distances together.

From a technical point of view most of us are familiar with two problems arising at the interface between “space syntax” and shape. First, how to determine the axial map in cases where solids are sparse and poorly aligned. Second, how to determine convex spaces in irregular free plans. These problems are not merely technical. They concern the extent to which “space syntax” can assist our understanding of how built space becomes intelligible, not at the level of graph-theoretic measures, but at the level of basic representations. These representations are intimately linked to the development of our intuitive comprehension of spatial phenomena. The underlying question regarding the interaction of shape and spatial configuration would remain open to theoretical debate, even if the technical difficulties are eliminated by resolving to use only the new representation presented by Hillier (1996) alongside the old, in other words, “all lines map” instead of the traditional “axial map”, and the “overlapping convex spaces" instead of the traditionally discrete convex spaces. The new representations take shape into account more systematically than the old, but they do not describe it as an autonomous object of study. They help us understand the consequences of the presence of shape but not how shape itself coheres in its own right. At the Georgia Institute of Technology, we have sought to develop new convex representations of plans that help us to better deal with the description of shape from the point of view of spatial configuration (Peponis et al, 1997). These methods provide us with alternative point of departure for applying the graph-theoretic measures of "space syntax." Here, I want to propose that the methods also provide us with a foundation for developing a calculus to reconstruct shape "from the bottom up", that is from the point of view of the moving subject. This is the particular problem raised earlier, and I want to show that it can be addressed in a framework which is compatible with "space syntax".

5 Convexity and informational stability with respect to shape

I will now proceed to introduce what we call the "endpoint partition" or e-partition (Peponis et al, 1997). Given a plan not including curves, we draw two sets of lines: first the extensions of the sides of reflex angles until they meet a wall surface; second the extensions of extendible diagonals, also until they meet a wall surface. Here, a reflex angle is one that is greater than 180°; a diagonal is a line that joins two discontinuities without crossing a wall surface. As a result of drawing these lines, we produce a great number of discrete convex spaces bounded by them. These spaces, which we call e-spaces, that have the following significant property. While we remain inside the same space and look around us, we can see the same set of discontinuities and the same set of wall surfaces, whether completely visible, or occluding. As we cross the permeable boundaries between these convex spaces, one or more discontinuities of built shape either appear into our field of potential vision, or disappear outside it. If we are willing to define a position according to the information about shape that is visually available to us from a point, we can say that this partition divides space into a finite number of informationally stable point-sets, and that it also helps us to reconstruct movement as a pattern of potential transitions between one informationally stable point-set and another. It will be noted that the manner of derivation of the e-partition resembles the derivation of the "all lines axial map" presented in Hillier (1996). There are two technical differences: we include only the extensions of diagonals, not the diagonals themselves; we also include the extensions of surfaces meeting at a reflex angle. There is a rather more significant conceptual difference. We seek to define informational stability with respect to shape, not potential lines of sight and movement. The e-partition of a simple shape is shown in figure 1.

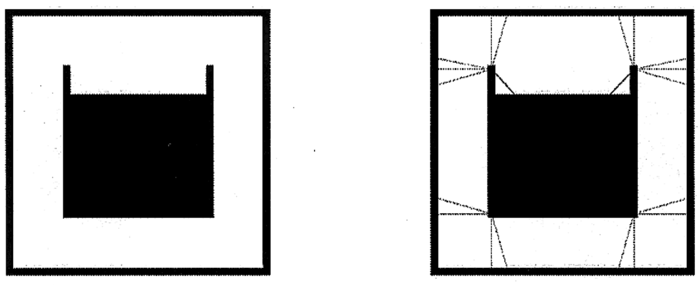


Figure 1. A shape and its endpoint partition.

6 Convex pairs and convex spans

The second idea I would like to introduce is simply a test of whether two convex entities are members of the same convex field. To enhance the relevance and applicability of the test, I propose that we should allow straight line segments and single points to be treated as limiting cases of convex entities, along side two dimensional convex elements. Given two convex entities, we suppose that we place an immaterial rubber band around them, without changing their position. If we can rubber-band them together so that the rubber band does not cross or contain any wall surface, then the two entities belong to the same convex field. From a mathematical point of view we are asking whether the minimum convex hull that includes the two elements crosses or contains wall surfaces. This test allows us to start from some convex element and identify all other elements of a similar or dissimilar convex elements that can be convexly paired to it. The set of all such elements I propose to call a “convex span”. It will be understood that the convex span of an element is not necessarily a larger convex space. The convex span can extend in several different directions. Here, I will be concerned with two kinds of convex span: the convex span of an e-space with respect to other e-spaces; and the convex span of a wall surface with respect to e-spaces. The first kind of convex spans allows us to approximate something akin to an adaptation of the “isovist”, by including not all points visible from one vantage point, but all convex elements all points of which are visible from all points of a vantage convex element. The second kind of convex span allows us to talk about the visual exposure of entire wall surfaces to space. It is quite significant to the argument that the increments of exposure of entire wall surfaces to our view, as we move about a complex, are complete e-spaces and never parts of e-spaces. The convex spans of an e-space and of a wall surface are shown in figures 2a and 2b respectively.

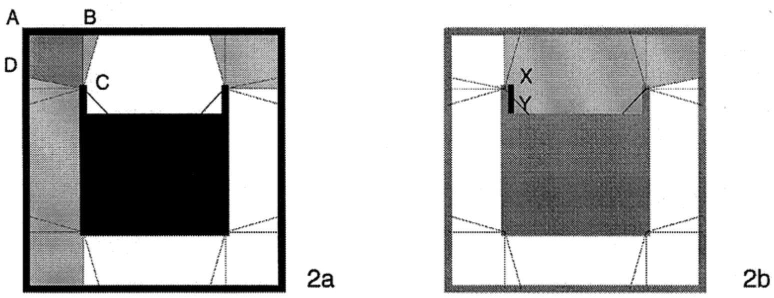


Figure 2.
2a: the convex span of an e-space (ABCD) with respect to other e-spaces; 2b: the convex span of a wall surface (XY) with respect to e-spaces.

7 The coordination of wall surfaces into sub-shapes

Wall surfaces intersect at edges. We can chose to describe the two sides of a free standing wall, as two surfaces meeting at angles of 360°. If we represent wall surfaces as filled circles and construct a graph where a line represents an intersection between surfaces, the wall surfaces of a complex will form one or more rings of variable size, as shown in figure 3. We can now introduce unfilled circles to represent e-spaces, and use lines between such unfilled circles to represent permeable adjacencies as we do with the representation of traditional convex maps. This is shown in figure 4. A third set of lines can be added to the graph. These lines go from a filled circle to an unfilled one and indicate that the entire wall surface is visible from the corresponding e-space. This rather complex graph is the conceptual foundation of the calculus that I want to propose. For illustration, it is presented in figure 5. It would be possible to develop an even more complicated graph, including links between e-

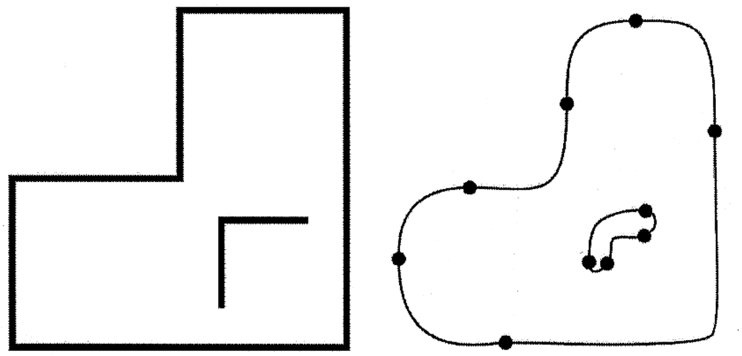


Figure 3. A shape and a graph showing the relationships of incidence between interior wall surfaces (filled circles).

spaces which can be rubber-banded together into a single convex field. None of these graphs needs to actually be drawn, once the ideas have been understood. The point is that the analysis proposed considers relationships between different kinds of elements, and allows relationships of different kinds to be applied to the same elements.

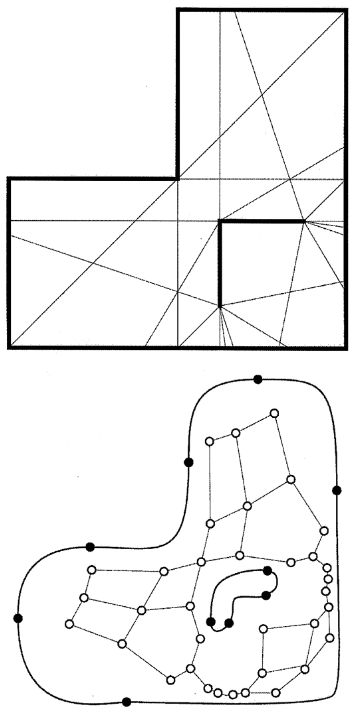


Figure 4. A shape with its e-partition and a graph showing the relationships of incidence between interior wall surfaces (filled circles) and the relationships permeability between adjacent e-spaces (unfilled circles).

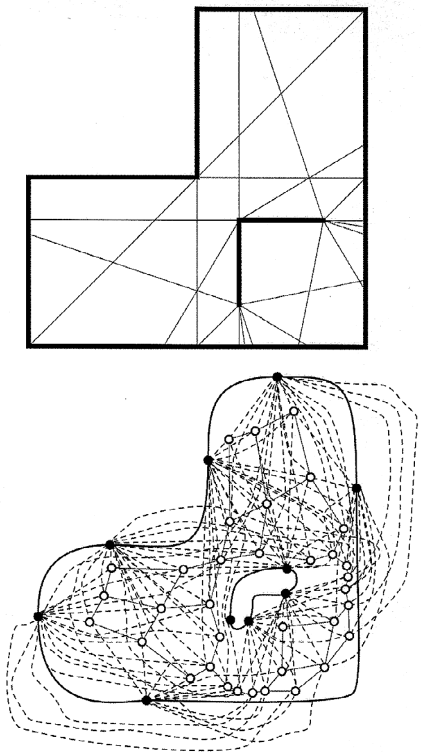
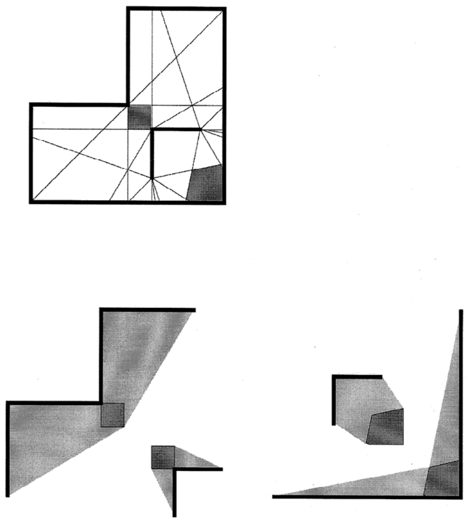


Figure 5. A shape with its e-partition and a graph showing the relationships of incidence between interior wall surfaces (filled circles), the relationships of permeability between adjacent e-spaces (unfilled circles), and the relationships between wall surfaces and the e-spaces from which they are entirely visible.

As a first step towards the coordination of shape elements, we identify the largest sets of connected wall surfaces that are entirely visible from at least one e-space. These sets can be treated as first order coordinated sub-shapes. Coordination, here, is simply based on the idea of simultaneous visibility. The eye can start at one end and move continuously to the other, without ever leaving the unfolding wall surfaces. The process is reversible. The reconstruction of a shape into first-order coordinated sub-shapes is illustrated in figure 6. I use the word "reconstruction" because the original definition of shape was entirely disaggregated.

8 Higher order shape coordination

We can now postulate the manner in which we can obtain higher order coordinations of the elements of shape. Two issues are involved. First, whether two sub-shapes meet at an edge or overlap along one or more complete wall surfaces. It would seem intuitively obvious that an overlap is a more powerful way of relating two sub shapes



than a shared edge. Second, whether the e-spaces from which the sub-shapes are constituted, are themselves convexly related, or whether they can only be linked through the convex spans of intermediate e-spaces. The theory and analytic procedure for dealing with these questions is still under development. Rather than discuss ideas which have not yet found a clear formulation, I prefer to conclude with certain remarks that demonstrate how this approach allows us to characterize shapes from the point of view of their coordinative re-constructibility.

Figure 6. A shape and the reconstruction of four first order sub-shapes consisting of wall surfaces which share an edge and are entirely visible from the same e-space. In this particular case, it is easy to see that the second order co-ordination into two sub-shapes could arise by linking the first order sub-shapes which are visible from the same e-space.

9 Proportional thresholds to shape coordination

Hillier (1996) has brought proportion within the scope of syntactic analysis by treating it, in the traditional manner, as a property arising when metric relationships can be established. For example, he has observed that the internal distribution of "integration" in rhomboid, square, and elongated rectangular shapes, is different, if "integration" is measured according to the pattern of transitions between modules of an underlying orthogonal metric. I want to argue that proportion can be defined syntactically, as a function of the coordinative potential of the emerging informationally stable convex units.

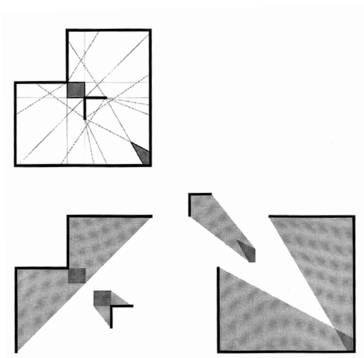


Figure 7. A shape and the reconstruction of four first order sub-shapes consisting of wall surfaces which share an edge and are entirely visible from the same e-space. The difference from figure 6 is the number of surface that....

Consider the shape in figure 7. In many respects, it has the same configurational structure as figure 6. However, the e-partition varies because e-partition lines produce more intersections, thus adding informationally stable spaces which were not present in figure 6. Some of the added e-spaces have greater first order coordinative effects. This is the simplest way of illustrating the occurrence of a proportional threshold affecting coordination. Consider, however, figure 8. Here proportions have been changes in such a way that two new, and very small, e-spaces have been added, which not only have greater coordinative power, but can also be rubber-banded together into a single convex field. It would appear that this new property, which was not present in either figure 6 or 7, will facilitate higher order coordinations. The example further helps to clarify how we can define proportional thresholds according to how shape can be reconstructed by the moving subject. The possibility of defining proportional thresholds on the basis of the underlying relations of incidence and convexity defined by the e-partition is quite significant from a theoretical point of view. Since no metrics are involved, it can be argued that the examples presented here illustrate a distinctive approach to the geometrical analysis of shape.

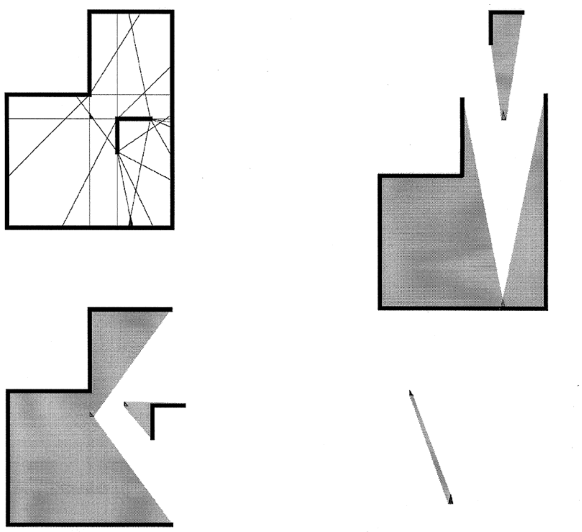


Figure 8. A shape and the reconstruction of four first order sub-shapes consisting of wall surfaces which share an edge and are entirely visible from the same e-space. The difference from figure 6 is not only that more surfaces become co-ordinated but also that the two e-spaces from which co-ordination is achieved are themselves in a convex relation to each other.

10 Concluding comments.

These, in summary, are the ideas I wish to bring to the consideration of the conference. I hope to have indicated how configurational analysis can be extended to deal with the reconstruction of shape from the point of view of the moving subject. It would seem that "space syntax," as currently defined by the work of the "Space Syntax Laboratory" at UCL, can be usefully complemented by other geometrical models of space and shape, so as to deal, in a compatible framework, with issues that have not yet been tackled in a concerted manner. In this way we can contribute to the development of theories regarding the intelligibility of buildings. That such developments are likely to make our analytic representations more design-relevant, by bringing them closer to the concrete architectural object, should be evident. At the Georgia Institute of Technology we are currently developing a suite of analytic routines on a Microstation platform. Our partners in this are "IdeaGraphix", Atlanta. We have called our developing software "Spatialist". The first set of routines, "Partitions", are already operational and will be demonstrated during my presentation.

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