In Fallingwater: Spatial structure at the scale of quasi-synchronic perception

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Abstract

Based on an analysis of Fallingwater we discuss the contributions space syntax can make to the study of the structures involved in spatial perception and its interface to cognition.

1. Is there a syntactic structure to the perceptual field?

Because built space cannot be seen all at once by its occupants, we come to understand it in terms of sequences of views made available through movement. Thus, from the standpoint of a situated observer, spatial structure can be defined as the invariant orders of relations that characterize such sequences, as for example when we recognize that coming into a supermarket it is unlikely that we will be treated to views of eggs or milk before we are exposed to at least some other goods. “Invariant sequential order” is an abstract idea. Does this mean that the study of spatial structure has a greater affinity with studies of spatial cognition than with studies of spatial perception?

Abstract relational properties of layouts are certainly implicated in the way in which spatial environments are explored and cognitively mapped. In the literature associated with “space syntax” the issue was first tackled by a research team at Georgia Tech (Peponis, Zimring and Choi, 1990). An excellent discussion of subsequent research is provided by Penn (2003) in a special issue of Environment and Behavior guest edited by Conroy-Dalton and Zimring in the aftermath of the Atlanta symposium on space syntax. Some key findings can be summarized as follows: the structure of connections captured by the line map of urban areas or complex buildings, such as hospitals, accounts for a statistical trend whereby navigation paths gravitate towards certain spaces more than others. People visit integrated spaces more frequently when they explore new environments or when they seek specific destinations which they are not already familiar with. When familiar with an environment, people also tend to remember more integrated spaces more frequently, and to include them in cognitive maps more often. Such statistical patterns of familiarization with integrated spaces would not arise if people moved randomly from random origins to random destinations, nor if they simply moved randomly out of assigned starting points. By implication, measures of the structure of connections, such as Connectivity or Integration, capture properties of layout that would appear to be cognitively intuited and encoded, whether directly or indirectly. The further question of what are the local choices that people may consciously make that might account for these statistical regularities has been increasingly addressed in syntactic research since the publication of the work of Conroy-Dalton (2003) who experimentally confirmed the tendency to opt for the path which preserves linearity as much as the environment will afford.

In this paper we discuss the intelligibility of spatial structure as it inheres at the scale of quasi-synchronic spatial relationships, that is relationships which can be perceived
almost all at once, with relatively little movement, or with movement that is held within a relatively constant horizon of spatial references. We argue that structural and syntactic relationships are entailed in spatial perception as much as they are entailed in spatial cognition. Put differently, spatial perception entails elements of construction, or rather of constructive understanding. At the same time, it is of special interest for having a closer link to aesthetics. The discussion will be based on a case study which is otherwise very well covered in the architectural literature, namely Frank Lloyd Wright’s Fallingwater. Before we start with the case study, however, some additional theoretical remarks are appropriate.

The work on the formal foundations of the syntactic analysis of space that was carried out at the Georgia Institute of Technology in the late 1990s addressed, among other issues, the question of whether isovist analysis as introduced by Benedikt (1979) (based on the theory of perception and environmental affordances proposed by Gibson (1986)), belongs to the same family of analytic ideas as convex or lines analysis which constituted the early back-bone of space syntax (Hillier and Hanson, 1984). In retrospect, it might not even be apparent why this would even be a problem. However, revisiting the issue is central to the argument to be developed here.

In some of the earlier literature of space syntax, syntactic relationships are said to be almost topological. This is linked to a broader belief that topological relationships are fundamental to both the way in which we understand space, as for example argued by Piaget and Inhelder (1967) and to the way in which social information is encoded in space (Levi-Strauss, 1963; Hillier at al, 1976). Over some of the intervening years, however, the assertion that space syntax deals primarily with abstract relationships, of the order of topology, has been sustained due to a matter of apparent technicality. The syntactic measures that were associated with most empirically tested research findings, including the ones reviewed above, are graph theoretic: Connectivity, Integration and Choice, bear clear affinities to the now standard graph-theoretic concepts of Degree, Node Centrality and Geodesic Betweenness respectively, as a result of what was, at least to some extent, a parallel rather than intersecting evolution of ideas. More importantly, Integration and Choice capture configurational properties that essentially arise as we look at the structure of invariant spatial orders. From this point of view, “topology” could be used as synonymous to “graph theoretic”, meaning “dealing with the invariant ordering of spatial relationships”. The isovist, describing what can be seen from a point, and the isovist field, arising as isovist properties change over a spatial domain, appeared to address something very different, namely, the changing configuration of boundaries within the perceptual field as a consequence of movement. Hence the intuitive concern that isovist analysis and space syntax, might represent different strands of spatial morphology.

Such concern arises from a poor way of formulating the issue. Space syntax is a graph-assisted, not a graph based theory of spatial description, which does not deal with topology in any mathematically precise sense of the word. Specifically, the graphs involved in syntactic analysis depend upon the prior step of reading building spaces in terms of lines, continuous or overlapping convex spaces, irregular shapes bounded by walls and doors, or, more recently, visibility polygons. There are two interesting correlates of this. First, from the point of view of a cognitive theory of space, these conventions are not arbitrary matters of expediency, to arrive at a graph. Rather, they stand for perceptually and cognitively significant elementary relationships. The lines map represents the scaffolding of minimum direction changes that covers a system, while the line itself provides a representation of the furthest potential destinations which can be at least partly perceived from a given
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position looking in a given direction. The convex map represents the maximal units of potential reciprocal co-awareness that are implied by a given disposition of boundaries. The boundary map that dominated some early analysis of building interiors captures the units of socially sanctioned access (on the assumption that a door traditionally represents a potential threshold of social control as well as an environmental filter). The visibility polygon represents the space that is potentially visible from a given position. Thus, the elementary relationships represented in graphs (intersections of lines, permeable adjacencies of convex spaces, intersections of visibility polygons) carry, in themselves, some theoretical hypotheses, regarding the elementary relationships according to which space is perceived, understood, and socially occupied.

This is only half the story. The other half is at least as relevant to the argument developed in subsequent sections of this paper. Those who sought to automate the generation of the lines map (Peponis et al., 1998; Turner et al., 2005), have discovered the rather unexpected conceptual and computational sophistication that is needed to move from a reading of the geometry of a plan to the identification of a uniquely specified lines-cover that satisfies the original specifications of the axial map. The implication, which applies to other forms of analysis (Peponis et al., 1997) is clear: a fully-fledged theory of syntactic descriptions involves theoretical ideas that bridge between plan geometry and syntactic representation. In my judgment this carries a rather significant philosophical corollary. From the vantage point of having crossed this bridge, we can state with greater clarity what the difference is between an elementary definition of built shape, defined as a set of spatially fixed maximal lines and surfaces, and the multiple elementary spatial relationships that arise as a consequence of shape. Here we refer not only to the relationships between the constituent lines and surfaces of the shape, but mostly to relationships that apply to the areas within, between and around them. In slightly more heavy handed jargon, the fundamental moment of retrieving descriptions of emergent structures within the theory of space syntax arises before we get to the graph, at the point when we recognize some of the potentially indefinitely many spatial relationships that arise by virtue of the existence of built shape, and attribute to these elementary relationships perceptual, cognitive or social significance.

This rather extended theoretical preamble helps to clarify why we are interested in reconsidering Fallingwater. One of the pertinent characteristics of Fallingwater is that on its main level, which comprises the primary living space, a rather rich set of spatial relationships is created by virtue of folding, recessing and projecting the perimeter of an otherwise unified main space. The many students of the building routinely acknowledge this. Levine (1996, 234) asserts that “the flexible, open plan is loosely organized around a central atrium-like space, illuminated from above by a large, nearly square, recessed ceiling panel, which is supported at its four corners by stone piers ... The various functions are zoned into pockets of space that pinwheel around this open core, sometimes overlapping and sometimes projecting from it”. Similarly Toker (2003, 234) says that “the living room ... is anything but regular in shape: depending on how you count, it has about a dozen major corners and another dozen minor ones. Nonetheless, most visitors will remember the living room as square.” Thus, Fallingwater is a good example of spatial relationships that exist in quasi-synchrony. We deal with two issues. First, what “space syntax” can contribute to our understanding of this particular space; second, and more important, what are the fundamental questions of theory that this particular example might serve to highlight.
2. The problem of discretization

Confronted with a subtly articulated architectural space, like Fallingwater, the fundamental question is what kind of discretization can capture its structure. Figure 12 presents the living space as a structure of convex spaces of the sort traditionally used in space syntax. In 12a the minimum convex partition is based on the floor plan. In 12e it takes into account the treatment of the ceiling: thus, the main space is divided into three zones; also, a rectangular office-library space is picked according to the geometry of the trellis. Otherwise, judgment is exercised in both instances of convex analysis regarding the level of detail that is taken into account in the convex break-up. The corresponding orders of integration show the main living space to be most integrated and the office-library to act as counterpoint on the segregated end of the spectrum. The entrance is also on the segregated end of the spectrum, so that one advances into greater integration as one walks into the main space. The more articulated interpretation depicted in 12e shows the living area to include a hierarchy of seating sub-areas, with the one attached to the fireplace more integrated than the one by the south windows which is in turn more integrated than the one associated with the music corner near the entrance. This same structure is preserved in the very simplified graph shown in 12i, where the effects of the detailed articulation of the perimeter are entirely ignored in order to abstract what seems to be the underlying relationships.

When extended to the house as a whole, this form of analysis might lend itself to capturing underlying socio-spatial codes of domestic space organization, of the sort introduced in “Ideas are in things” (Hillier at al, 1987), enriched and extended by Hanson (Hanson, 1998) and taken up again, with different critical aims, in Bafna’s work on Mies’ plans (Bafna, 1999, 2001). However, quite clearly, it does not lend itself to capturing the perceptual properties of the space, nor to theorizing the link between perceptual properties and underlying socio-spatial codes. There are at least two reasons which are both quite straightforward but not at all uninteresting. First, this analysis discusses the order of access without recognizing that in the context of an open plan access is counterbalanced by visibility: what good is it to say that the dinning area can only be reached after we traverse the main living area without taking into account that the dinning area is almost universally co-visible with the living area? Second, the transition from the plan, with all its density of potential spatial relationships, to the discrete representation is imposed rather than derived from the plan itself. While in more cellular arrangements the boundaries implied by the graph lend themselves to more direct perceptual associations with walls or other physical elements, here the relationship between transitions and the physical object is tenuous. Hence the sense of disconnection between the object manipulated by the architect and the abstracted object reconstructed by the analysis. If pursued and extended through comparisons, the analysis can probably capture how underlying cultural codes inhere in the object but it cannot capture what design does to the specific manifestation of these codes as a particular work of architecture. In the next four sections we will discuss spatial structures inherent to the living space of Fallingwater in ways which are more sensitive to the local structure of shape and design. In the course of the analysis, higher order forms of discretization will emerge from a consideration of much more pervasive relational structures.
Figure 12: Living space, Fallingwater: convex analyses.
3. Transformations of centrality in Fallingwater

We will begin by considering the problem of centrality in Fallingwater, as initially manifest in the tension between a peripheral arrangement of behavioral settings and the creation of a figural center through the treatment of the ceiling. The methods of syntactic analysis that we will use are the e-partition ( "Spatialist" licensed through Georgia Tech) and visibility graph analysis ("Depthmap" licensed through Space Syntax Ltd). These are entirely constructed according to the geometry of shape, at a very disaggregated level of analysis. Fallingwater provides us with a good case study to help discriminate between them. The e-partition (Peponis et al, 1997) represents a layout in terms of constituent convex spaces that are stable with respect to visual information. The same corners or wall end points are visible when you remain in the same e-space; at least one corner or wall end point either appears or disappears from the field of vision if you cross the boundary between any two e-spaces. Visibility graph analysis (Turner, 2001) is essentially capturing the directional distance of area from all locations. The analysis is based of flood filling space with a tessellation of tiles at a chosen level of resolution. Graph connectivity captures the number of other tiles visible from an individual tile, thus the area which is directly visible (and accessible if the analysis is carried upon a plan taken at knee rather than eye-level). Visibility graph depth captures the number of direction changes needed so as to see all available area from a given position. The integration structure of the living space in Fallingwater based on e-partition analysis and visibility graph analysis is shown in figure 13.

As analyzed here, the integration core of the e-partition comprises the spaces which are few information thresholds away from all other spaces. Thus, it represents the informational center of the layout. The location of the integration core is relatively stable for three different frames of analysis: First, the interior and exterior space as defined by major boundaries; second the interior space at eye level; and, third, the interior space at knee level. One end of the integration core is always attached to the free standing pier next to the stair descending towards the water. The other end extends diagonally towards the dinning area. In all cases, the e-partition integration core does not coincide with the figural center of the living space. Instead, the e-partition core crosses towards the seating area next to the entrance.

The integration core revealed by visibility graph analysis comprises the area from which the rest of the layout is few visual steps away. By contrast to the e-partition, the location of the integration core of the visibility graph changes dramatically depending on the framework of the analysis. When exterior space is included, the core becomes associated with the south boundary and the seat, irregularly extending towards the interior space associated with the pier. When eye level interior space is analyzed, the integration core seems to capture two of the edges of the figural center, while also drawn towards three of its corners , the ones which most clearly stand out as concave edges of the physical boundary. When considering knee level interior space, the core is drawn into the figural center almost entirely, with a bias towards the southwest, that is the direction of the best external views.

Fallingwater, therefore, is characterized by three kinds of centrality. Figural centrality, inscribed by the architect; shape informational centrality; and visibility centrality. The three kinds of centrality do not coincide, so that we can speak of a dynamics of centrality: Fallingwater has focal regions, or perhaps a distributed center, not a single focal point. What is the relevance of this? To offer an interpretation we must first ask what the
Figure 13: Living space, Fallingwater: e-partition and visibility graph analyses.
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relevance of visibility centrality is. Why should the visibility of area matter to the theory of space syntax? One way to answer this question, particularly with respect to the living area of Fallingwater but also more generally, is to suggest that area is the field of potential presence of other people. Then, the e-partition and visibility graph analysis would look at space from two complementary points of view: the manner in which space emerges according to the elaboration of the physical shape of the building; and the manner in which space acts as a field of co-presence. So, at Fallingwater, visual integration to the area that can be occupied by people oscillates between two poles, one marked by the major in-built seating and one marked by the figure at the ceiling. Visual integration to information about shape is drawn closer to the back wall, stretching inwards from the free-standing pier.

To say so will give the impression that inordinate analytical effort has been expended to arrive at insights that might have been intuitively accessible to most architects. Making our intuitions precise, however, is not the sole aim of our endeavor. A more substantive issue is at stake. Like many other buildings, Fallingwater presents a clear distinction between front and back. In Fallingwater this takes the particular form of a contrast between the “furnished cave” (an expression Levine attributes to Frampton) and the cantilevered tray or terrace, offering views of the creek. We show this in figure 14a and b. Figure 14a abstracts two principles involved in the design, the intersecting slabs which become most apparent in the well known photographs from the lower waterfall, and the thick stone wall which embodies the principle of a surface folding into a meander. Figure 14b shows how the two principles come together, with the piers acting as the major locking devices. Under the purview of these principles, the distinction between front and back is elaborated using a number of devices that range from the contrast between stone, glass and painted concrete surfaces to the treatment of light. The point of our analysis is to demonstrate how the distinction is also inscribed in the structure of built shape and in the perceptual structure of space that is generated from it. The manner in which Frank Lloyd Wright has inflected the shape of the living area renders the differentiation of front and back in terms of a purely spatial structure of the perceptual affordances of environment. The back has the greater number of recesses and folds, so that informational centrality is pulled towards it. The front provides more direct views of available space even when visibility at a distance beyond the building is not taken into account. When the impact of built-in furniture is included in the analysis visibility centrality is brought into closer correspondence with the figural center. In short, shape and space are tuned to architectural intentions and perceptual orientations which are also expressed through other devices. We will take up the question of tuning from a different point of view in the next section looking from the distributed center out towards the diversified periphery.

4. The tuning of shape and space to other kinds of visual interest

Fallingwater is one of the most photographed and perhaps most photogenic buildings of modern architecture (Levine in Stoller, 1999; Toker, 2003). As a result, it enables certain kinds of analysis that would not be as easy in the case of other buildings. In this section we examine a sample of 34 photographs published in three key books (Hoffman, 1978; Stoller, 1999; Kaufmann, 1986). The time when the photographs were taken does not correspond to publication dates. Hoffman’s book shows photographs by Hedrich-Blessing, taken in the 1930s; these are the photographs that made Fallingwater famous through
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Figure 14: Fallingwater main level: reconstruction of conceptual generative relationships.

the Architectural Forum special issue and the MoMA exhibition in 1938. Hoffman also includes photographs by Corsini taken in the 1960s as well as photographs by himself. Stoller’s book presents the photographs he was commissioned to take for the Museum of Modern Art exhibition in the 1960s which coincided with Fallinwater opening to the public. Kaufmann’s book shows some older as well as some new photographs. The sample of photographs we analyzed includes all photographs published in these three books and taken from inside the living area: 10, 11 and 13 photographs respectively. For each photograph we were able to determine the viewing point approximately, based on the pattern of intersection of extended occluding edges. We also located the edges of the photograph on the plan, with greater certainty. A representation of “the data” is offered in figure 15.

We looked for correlations between the frequency with which each portion of the boundary of the living area shows up in photographs and the syntactic properties of that portion based on visibility graph analysis. For the purposes of this exercise we looked at the interior only, taking the boundary at eye level. Visibility graph analysis was done for the space as a whole (asking how visible is each portion of the boundary from all positions in the living area) as well as for the boundary only (asking how visible is each portion of the boundary from other portions of the boundary). As shown in figure 16, in all cases, syntactic variables predicted at least 25% of the frequency variation. For the Stoller and Kaufmann sub-samples as well as for the sample as a whole, the best predictor of the frequency of appearance of a portion of boundary in the photographs is the Connectivity of that boundary portion with respect to space; in the case of the Hoffman sub-sample the best predictor is Integration.

This is a rather new way of analyzing the exposure of sections of buildings in photographs, but what can we learn from it? It would certainly be inappropriate to infer from the correlations that photographers are somehow adjusting their choice of subject matter according to the syntactic properties of boundaries. Clearly, photographers aim their camera according to a range of criteria of visual interest, including the pictorial content...
Figure 15: Views corresponding to a sample of 34 photographs taken inside the living space at Fallingwater.

of a view, the quality of light, or the informational content of a frame depending on what they wish to communicate about the building. At most, the syntax of space might be one of the criteria directly or indirectly taken into account. Furthermore, if, for the sake of arriving at a null hypothesis, we suppose that a robot is placed a large number of times at a random location within the plan and takes a photograph facing in a random direction, we can see that for a sufficiently large sample of photographs, the likelihood that a portion of the boundary would show up in a photograph would be in direct proportion to the visual connectivity of that portion of the boundary. Thus, most of our findings are consistent with the null hypothesis. But why should a relatively small sample of photographs taken by professional photographers according to a variety of criteria of interest behave in this manner? One possible explanation, that we propose here, is that the spatial properties of the boundary, and the resulting space, are “tuned” to other aspects of visual interest, including pictorial or visual interest. This is a rather pertinent statement to make about architectural design. If space is fundamental to architecture, it is so precisely because it provides the framework within which perceptual and aesthetic interest are organized and coordinated. Accordingly, if our finding has a more direct cognitive import, the cognitive import has to do with the nature of architectural design.

The analysis of architectural photography is only an experiment in a line of inquiry still being developed. We include it here because it suggests that the same underlying relational structures which govern the distribution of centrality, also affect the manner in which space is depicted in the medium of photography. We suggest that photographs of buildings, where available in some abundance, can be treated as data about the interface between spatial perception and structure. In this particular case, the analysis supports the idea that in architecture, visual interest and visual information are tuned according to the more abstract syntax of space.
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<table>
<thead>
<tr>
<th></th>
<th>Hoffman</th>
<th>Stoller</th>
<th>Kaufmann</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Integration with respect to space</strong></td>
<td>$r^2 = 0.247$</td>
<td>$r^2 = 0.279$</td>
<td>$r^2 = 0.419$</td>
<td>$r^2 = 0.550$</td>
</tr>
<tr>
<td><strong>Connectivity with respect to space</strong></td>
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<td>$r^2 = 0.359$</td>
<td>$r^2 = 0.496$</td>
<td>$r^2 = 0.566$</td>
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<tr>
<td><strong>Integration with respect to boundary</strong></td>
<td>$r^2 = 0.194$</td>
<td>$r^2 = 0.282$</td>
<td>$r^2 = 0.409$</td>
<td>$r^2 = 0.520$</td>
</tr>
<tr>
<td><strong>Connectivity with respect to boundary</strong></td>
<td>$r^2 = 0.210$</td>
<td>$r^2 = 0.290$</td>
<td>$r^2 = 0.457$</td>
<td>$r^2 = 0.519$</td>
</tr>
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All correlations shown are significant at 1%.
5. Furniture and the discretization of spatial relationships

The spatial disposition of furniture within a setting can be analyzed as a reading of
the affordances of the setting in relation to behavioral or functional intentions, and as
an inscription of the pattern of space-use within the context of a setting. In Fallingwater,
built-in furniture is an important part of the design. All built-in furniture is attached to the
boundary. In fact, the design is such that each piece of furniture works with the section of
boundary to which it is attached in order to produce a visual figure, that is a self contained
visual composition. The set of photographs published in Kaufman (1986) recognizes these
figures. A larger proportion of frontal photographs is evident as compared to the other two
sets which are mostly biased towards diagonal views. The frontal photographs are aimed at
foregrounding the figures of the fireplace, the main seat on the south side, the dinning table
with shelves in the background, the music alcove and seat by the entrance, or the seat by
the fireplace. We will look at built-in furniture from two points of view. First we will look
at the properties of the space occupied by the furniture, using the analysis shown in 2d as
a basis. Second we will look at the properties of the boundary section associated with the
furniture. In essence, we average the visibility integration values associated with the space
occupied by the furniture, and the boundary visibility integration values associated with
the boundary portion to which furniture is attached. Our analysis includes consideration
of the stairs and entrance threshold, which are quite tightly defined and circumscribed
regions of space. We also consider the protruding surface of the boulder, in front of the
fireplace; this can act as a seat but is much more that natural furniture. It is the conceptual
support as well as part of the literal foundation of the house, it carries the memory of the
Kaufmann family visits to the place before the house was ever built.

Analyzed in this manner, furniture can be interpreted as an accentuation, or invest-
ment, of segments of the range of visibility integration values produced by the shape. This
is shown in figure 17. The histograms at the top of the figure have intervals of integration
values on the x-axis and frequency counts associated with these intervals on the y-axis.
They represent the range of visual integration conditions that emerge by virtue of the
shape. The average values associated with pieces of furniture (using a very fine grain in
Depthmap) as well as with some clearly defined regions of space, such as the entrance
threshold or the stairs, are marked over the histograms. We also provide integration in-
equalities, to underscore the rank order of furniture according to integration.

Stairs as well as the entrance threshold occupy less integrated areas of space than
any of the furniture (17a). The wall associated with the stairs going up lies in the least
integrated end of the spectrum (17b). Thus, the space is so arranged so as to provisionally
suspend the awareness of destinations beyond and to emphasize the pattern of co-presence
of furniture, behavioral settings and visual figures instead. The dinning table and the
boulder are associated with the more integrated areas of space; the office desk and the
major seat on the south side hold the next ranks (17a). The office desk, the dinning table,
the fireplace and the major seat on the south side are associated with more integrated
sections of the boundary (17b). Taking these findings in conjunction we recognize the
special significance given to the positioning of the dinning table. Surely, the placement
indicates a visual choice regarding how it is to be looked at, rather than a visual choice
regarding what is seen when sitting around it (the seat at the head of the table only
faces the wall, the seats on either side face the stairs and the kitchen door respectively,
with only oblique views towards the fireplace from one side and towards the office and
library alcove on the other). In placing the table at this position Frank Lloyd Wright
would plausibly have intended to associate it with the boulder and fireplace to create a composite image of hearth and domesticity. This is certainly an intention that can be read in the decision to run an upper shelf from the outer end of the wall carrying the fireplace, all the way around the inner corner of the house, to the embedded stone pier associated with the dining table, as if to bracket the composition into a whole. As if in tribute to this intention, many of the photographs considered above are oriented towards the “fireplace - dining table” corner of the house, more than towards any other part.

The relative visual prominence of the main seat on the south side is a counterpart to the prominence of the dining table. If the table is associated with the meandering inner wall, the seat is associated with the more open part of the perimeter. Moreover, seat, figural center, free standing piers and table create an axially symmetry sub-shape within the house as shown in figure 14c and 14d. Frank-Lloyd Wright is signaling the deliberate opposition between front and back. Curiously, this is not as often noticed in the literature as two diagonal oppositions. The first runs Northeast to Southwest from the entrance enclosure to the terrace and the open views. The second runs Northwest to South East from the fireplace, boulder and chimney, to the stairs leading to the water with the trellis skylight over them (Kaufmann, 1986). The diagonal oppositions thus work to orient the house symbolically, certainly to the site, and possibly to more cosmological references: earth, water, fire, air (the later interpretation disputed by some authors such as Toker, 2003). Levine (1996) sees the second diagonal emphasis as deliberately inscribed in the resonance between the semi-circular shape of the back of the fireplace (which replaced an earlier semi-octagonal treatment) and the semicircular boundary associated with the stairs to the water. The recognition of the first diagonal is based on more evident perceptual qualities.

The axis highlighted by our analysis is not only inscribed in the design more deliberately than the second diagonal, it also has more subtle perceptual qualities than the first. Remembering figure 13 we can see that the seat is associated with the visual integration core taking the terraces into account, while the dining table is associated with the informational integration core. Thus, the analysis of the spatial disposition of furniture can add to our appreciation of the house as a product of architectural intentions. More importantly, it can help us understand how some of the spatial relationships that are more diffusely realized in the plan are foregrounded and discretized, so as to register not only perceptually but also cognitively. Understanding the discretization of relationships rather than of spaces as a result of design is the main import of the analysis. The cruder convex analysis presented earlier was unsatisfactory because it only highlighted relationships at the cost of what appeared a forced discretization of space. The more sensitive analysis that followed has the advantage that it can account for the foregrounding of relationships without such cost.

6. Figuration and occlusion

The insertion of figures in the field of spatial relationships affects not only their relative visual prominence but also the manner in which they are viewed. To begin with, each figure, with the exception of the main seat on the south side, is associated with a fold of the boundary. By implication, the viewing cones directed at the figures have occluding edges, implying the extension of space outside the visual frame. Furthermore, in making the transition between any two sequential figures along the boundary, we always go through
Figure 17:
at least one concave corner which splits the visual field and creates occlusion. These two observations, however simple, have an interesting consequence that one is intuitively very aware of when visiting Fallingwater. The figures are not revealed as so many sculptural reliefs along a museum wall. They become part of the boundary, their own visual presence is intimately associated with the transformations of the visual field produced by its folds, its recesses and its corners.

Supposing now that each figure draws subjects towards it so that its neighborhood becomes a viewing platform from which to look at the other figures, 30 directed binary relations of visibility are defined between the following: fireplace, dining table, office desk, south seat, west seat, east seat. In 18 cases the relation runs across an fold of the boundary that partly occludes the visual field. In technical terms, the convex hull that contains the two figures intersects a part of the boundary. This means that from at least some positions in the vicinity of a figure, other figures are only partly visible, not entirely. In addition, in 20 cases the visual field extends behind the viewed figure but comprises an occluding edge. By implication, the viewer is aware of the figure becoming enwrapped in space.

These conditions implicate potential movement in the viewing of figures either in isolation or as parts of a configured space. To be sure, there are viewing angles and viewing distances from which figures appear self contained. These are documented in the set of photographs in Kaufmann (1986). More often, however, as shown by the majority of the photographs, the viewing of figures involves occluding edges both between the viewer and the figure and behind the figure. One aspect of the spatial character of Fallingwater is the dissociation of figure from static viewing and from the creation of finite sub-spaces. Figures become devices that invite movement, not in the interests of discovering new spaces (the stairs and entrance occupy the least prominent positions) but rather in the interests of discovering new relationships in the space of quasi-synchrony. If we allow ourselves at all to interpret the distribution of viewing points shown in figure 16, we see that viewing points cover both the e-partition integration core and the visibility integration core arising when the terraces are included in the analysis. We also see that some of the viewing points are associated with orientations towards periphery and some with orientations across the interior, so that viewing points and viewing cones constitute a collective mesh that captures not just the space itself but rather the replete spatial structure that it engenders. Figures are there not so much to fix a view and claim it, as to wink an eye towards the distributed collective of other potential views.

7. Replete synchrony and the methodology of space syntax

Distributed centrality, the inscription of the distinction of front and back in the shape of the living area, the tuning of shape to other aspects of visual interest, the creation of axes mediating different poles of perceptual emphasis such as openness and closure, the use of figures to highlight and discretize certain relationships, the co-visibility of figures so as to encourage a distributed sense of viewing, all these characteristics of Fallingwater that have been highlighted above work together to create a sense of a replete structure, where the differentiation of behavioral settings and perceptual conditions works in the context of quasi-synchronous perception.

What broader methodological principles, in addition to the ones already discussed in the course of the argument, might be suggested by this case study? The answer to this question lies in the nature of interaction between shape, space and graph in the theory
of space syntax. From a rather simplistic point of view, the analysis used more miniscule spatial partitions in order to read discrete graph-theoretic relationships into the plan. Could it, therefore, be said that reading of shape always remains preliminary to graph analysis however sophisticated and substantive the theory associated with it might be? I suggest that quite on the contrary, the argument has involved a critical step that should not go unnoticed, nor be taken for granted. The results obtained from graph analysis are projected back onto shape and space. This projection leads to the recognition of latent sub-shapes arising, as it were, from our consideration of spatial relationships. A moment’s reflection suggests that the graphic output associated with space syntax is not merely a way to visualize the rank order of discrete elements according to some measure. The graphic output serves as a diagrammatic device that mediates the recognition of higher order relationships, and emergent spatial elements arising according to such relationships, as for example with the distinction between the information, visibility and figural centrality. This is why, in the most pedantic terms possible, juxtaposing a graph to a plan as in figure 12 is not as powerful a representation as superimposing the results of graph analysis on the plan itself, as in figure 13. The former representation reifies and freezes both elements and relationships. The latter highlights the interactive construction of elements and relationships. To be sure, the sub-shapes are contingent upon arbitrary conventions about the “break off” points chosen in the course of the analysis; the shape of integration cores, for example, depends to some degree upon the percentage of spaces included in the core. The shifting nature of sub-shapes, however, is immaterial; the important thing is to recognize that the ranking of discrete elements according to a quantitative relational property is not the end of the analysis.

Quasi-synchrony makes the interaction between discrete relationships and emergent sub-shapes more tangible because the sub-shapes are there to be discovered in the perceptual field, as it interacts with cognitive and imaginative reconstruction. As we look at the living space of Fallingwater from different points of view, we come to see it in different ways. When we deal with larger scale environments emergent sub-shapes can only be perceived as part of the mental image of the object, not directly. Hence they appear not only as more abstract but also as more disembodied. In quasi-synchronic environments the imaginative interaction between perception and cognition can more easily be projected back onto the object so that abstraction complements concretion. Nevertheless, the interaction between the original reading of shape in discrete terms, the analysis of graph theoretic properties of the discrete system, and the emergence of higher order sub-shapes remains central to the contributions that space syntax can make to our understanding of spatial perception and spatial cognition.

**Literature**


