Top-down and bottom-up characterisations of shape and space

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Abstract
This paper explores methods for establishing an integrated analysis for the description of shape and spatial properties. Its aim is twofold: first, to test the analytic methods against shapes of simple and moderate complexity. Second, to account for ways in which shape patterns are revealed during spatial experience. The analysis quantifies syntactic properties of shape perimeter focusing on the measures of connectivity and integration. These are studied in two levels: the level of configuration seen as a static notion and the level of configuration as a dynamic notion unfolding through time. It is proposed that syntactic regularities of shape can be described as regularities in the patterns of sequential information, or otherwise as regularities in the temporal structure of information transmission.

Keywords
time, movement, shape perimeter, rhythm

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> "Almost instantly, I saw it – the garden of forking paths was the chaotic novel; the phrase 'several futures (not all)' suggested to me the image of a forking in time, rather than in space. A full rereading of the book confirmed my theory. In all fictions, each time a man meets diverse alternatives, he chooses one and eliminates the others; in the work of the virtually impossible - to disentangle Ts'ui Pen, the character chooses - simultaneously - all of them…Unlike Newton and Schopenhauer your ancestor did not believe in a uniform and absolute time…"

Jorge Luis Borges, 'The Garden of Forking Paths', Fictions, Penguin Books 1998.

Shape configuration and spatial experience

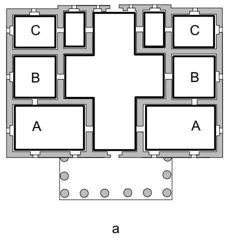
The distinction between shape and space centres on the notion of time. A shape is an conceptual pattern that can be seen and grasped at once. On the other hand, space is a structure of visual fields that are seen gradually through movement. The difference between a pattern that is understood instantly and a pattern that unfolds in sequence is what distinguishes architecture, literature, music and film, from the visual arts. But whereas the other forms of serial art are purely based on time, architecture combines the sequential nature of space with the simultaneous framework of shape.

However, most analytical accounts divide between top-down descriptions of geometrical order and bottom-up approaches based on spatial relations. Space syntax describes layouts as patterns of permeability and visibility connections experienced from the ground. Nevertheless, it does not account for shape properties or the ways in which these properties are accessible during spatial experience. The purpose of this paper is therefore twofold: First to explore ways in which a single analytical framework can be achieved for the quantification of shape and space. Second to describe the ways in which shape and space are sequentially linked through the notion of time.

Time can be defined in two ways: as succession and as order. Time as succession is a sequence of states that unfold one after the other like a narrative. Time as order consists of patterns by which the episodes in the linear chain are linked across the sequence. Structural relations like rhythms and symmetries establish periodic patterns that link elements outside their position along the line. An enfilade sequence of spaces is an example of time as succession, figure 1a. In a classical villa moving from one enfilade series to the one at the opposite side we experience a group consisting of two rooms that are repeated three times, or a group of three rooms that occur twice. The symmetry on the back to front axis can be seen from the central space, but can be also inferred through the periodic recurrence of spaces. Time as order is defined by these rhythms and is experienced through time as succession. Symmetry in itself is an absolute notion that exists independently of the sequence through which it is presented. However, its retrieval is time based and sequential time is the only medium in which it can be seen.

In an open plan, rhythm enters our experience not through individual rooms that are repeated in sequence, but as surfaces that are gradually synchronised. Figure 1b-e shows a series of isovists drawn from each corner of the space[1]. Figure 1f-k presents groups of two overlapping isovists. Each isovist in a group shares two whole surfaces and a part of the surface adjacent to those that are seen as wholes. As we move clockwise from the bottom left corner, certain surfaces remain constant while others disappear from vision. Those that stay constantly visible in all isovists are marked in figure 1l. Their property to connect views from different locations and their symmetrical positioning are confirmed only after all corners are visited. Unlike the enfilade arrangement, symmetry is grasped not through a repetition of identical enclosures, but through the repetition of identical patterns of overlap amongst identical isovists.

Isovists and their overlap are at the centre of space syntax research (Turner and Penn 1999) and similar analytic developments (Peponis et al 1997). Although these studies make an important contribution to the description of space, they approach it mainly through the notion of configuration. We propose that configuration accounts for global and local properties, but is not equivalent to spatial experience. The former is an invariable notion. The latter is a structure of visual patterns that vary or repeat themselves periodically in time. It will be suggested that configuration enters spatial experience based on temporal patterns in the structuring of visual information.



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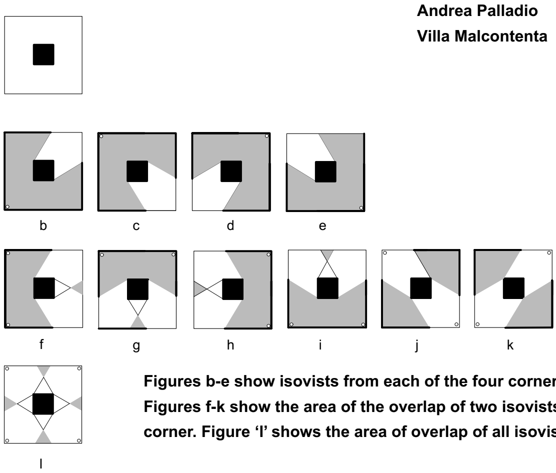


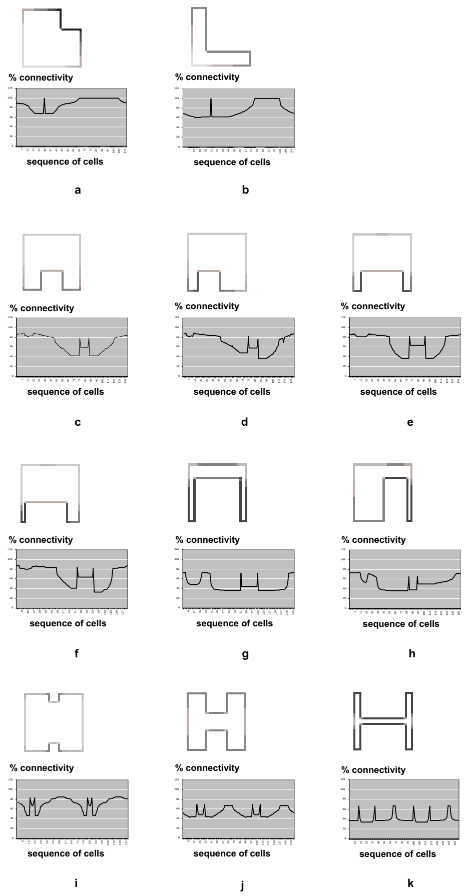
Figures b-e show isovists from each of the four corners of the shape. Figures f-k show the area of the overlap of two isovists, each from a corner. Figure 'l' shows the area of overlap of all isovists.

Figure 1
(a, b, c, d, e, f, g, h, i, j, k, l)

Measuring shape perimeter using local properties

Our analysis starts by looking at the syntactic properties of shape perimeter represented by a set of square units that are joined facewise. Using a GIS computer model developed at the Welsh School of Architecture we measure the connectivity value of each square as the average set of perimeter points visible from that location. We can thus provide a categorisation of shapes based on syntactic properties of their surface, figure 2a-k. Studying configurations with varying degrees of occlusion and symmetry in previous research led to the following observations: First the distribution of values, shown in different shades of grey, captures the geometrical regularities in the shapes. Second, changing the metric properties or symmetry in a shape we affect the inter-visibility of its locations. Comparing figure 2c with its asymmetrical variation shown in figure 2d for example, we see that there is a slight increase in the values from the symmetric to the asymmetric arrangement, Table 1. These differences confirm common intuition in terms of the effect of asymmetry in creating differentiation in design.

The next step in the analysis is to represent the transitions of values at a fine level of detail using a graph that plots connectivity for each grid square starting from the top left corner and progressing clockwise, figure 2a-k. The horizontal axis represents the sequence of cells. The values on the y axis map the connectivity levels for each point as an average of locations included in its isovist. They also provide the extent to which each location is seen by other perimeter points, as the property of visibility is interchangeable. Fluctuations of the graph on the y axis capture the changes in connectivity value and the changes in the extent to which each point survives in serial vision.



		mc-value	i-value	v-value	R-square
	a	69.93	21.55	16.51	0.97
	b	70.24	21.86	16.86	0.96
	c	67.31	19.29	18.74	0.98
	d	67.4	19.32	18.86	0.98
	e	44.78	8.08	12.15	0.91
	f	51.48	9.16	13.24	0.82
	g	75.22	21.81	10.32	0.95
	h	52.33	9.4	8.30	0.92
	i	39.49	6.60	8.14	0.62

Table 1

Figure 2 (a, b, c, d, e, f, g, h, i, j, k)
The distribution of connectivity values captures the geometric regularity in the shapes. The transition of values is shown through graphs starting from the top left corner of the shape and plotting values clockwise.

We can study these graphs by looking at the patterns of fluctuation of the curve along the vertical direction. These account for changes in connectivity values with low and high values within each peak and trough respectively. The level of differentiation amongst values can be calculated using the measure of standard deviation (v-value). High standard deviation suggests high degrees of dispersion or differentiation amongst perimeter locations. In Table 1 we see that from figures a to d v-values increase indicating increasing degrees of differentiation. In figures e-i these values generally decrease showing high levels of stability. Shapes like figure 2a are stable along a great extent of the perimeter length at the top end of the scale of connectivity values. In contrast, shapes that are characterised by high degrees of occlusion like in figure 2b, 2g, 2j-k have low v-value and are therefore stable at the bottom end of the scale. Low v-value is an outcome of occlusion and geometrical symmetry in a configuration and expresses the extent to which repetition exists in the pattern of visual information.

Measuring shape perimeter using global and local properties

The measure of connectivity can sufficiently describe simple configurations. In more complex shapes it is essential to use global measures like integration. This accounts for how close each perimeter point is to every other location (Hillier 1994). The calculation of integration is based on graph theory using the notion of mean depth between each element and every other element in the graph. In our analysis points which are inter-visible, i.e. those found in the same isovist, are situated at the same depth level. Points that are not inter-visible are one depth level apart and so on.

Similarly to the connectivity values integration generally decreases from the first to the last figure, indicating the effect of cutting into the shape and introducing depth in the configuration, Table 1. Figures 3a-i show corresponding graphs of connectivity and integration values We see that the two graphs follow a roughly similar course along the x axis rising and falling at similar positions. This indicates that every time a point is more connected it becomes also more integrated. Another way to study this relationship is to produce ‘scattergrams’ for the two variables, figures 4a-i. Each point in the scatter represents a perimeter square unit. Its location on the x axis is given by its integration value, while that on the y axis by the connectivity value. We see that in all figures the plotted points are distributed along a curved line. This means that although the two variables increase and decrease together, their rate of change is different for different parts of the curve. At the bottom range of values connectivity rises faster than at the top end. Integration behaves in the opposite way, increasing slowly at the beginning and faster at the other end of the scale.

These results show that in the segregated parts of the shape there is more change in terms of local scale information than information about the configuration as a whole. In contrast, in the integrated areas there is little differentiation in terms of what is visible locally and more differentiation in terms of where each point stands in relation to the whole.

The reason behind the difference in the two rates is illustrated in figure 5a,b. In the first figure the incremental increase in the perimeter of the isovists drawn from points that have a low connectivity, and integration value is lower than the increase in the perimeter of isovists drawn from integrated positions. As the reflex angles intrude more into the central area of the shape, figure 5b, the increase in the perimeter of the isovists drawn from respective positions and consequently the rates of change of connectivity and integration will tend to become more similar. Looking at the figures 4e-i we see that apart from figure 4g the points cluster along a line that has a much shallower curve indicating more similar rates of change. We also see that the correlation is weaker than previously as there are points at the bottom left side of the scatter that are positioned above and below the regression line.

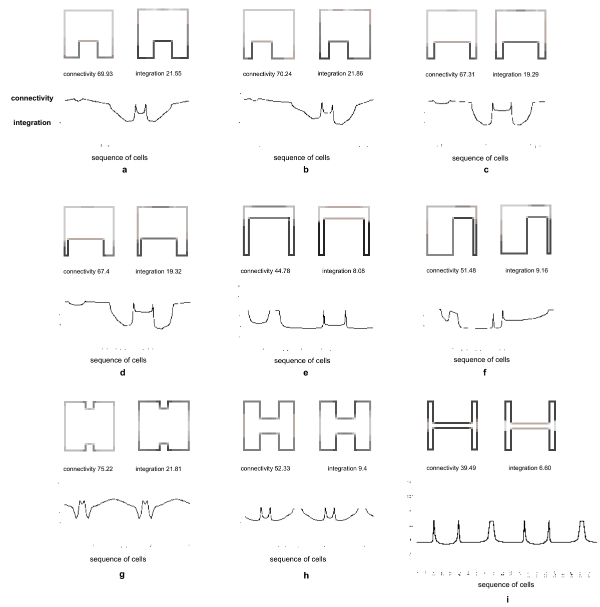


Figure 3: Graphs showing mean connectivity values (black line) and integration (white line) at a fine level of detail. The graph line starts from the top left corner of the shape and progresses clockwise. Connectivity and integration tend to follow a similar course rising and falling at the same locations.

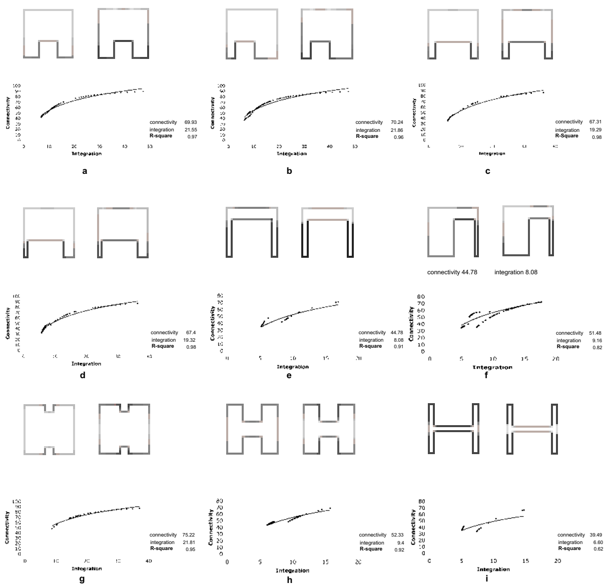


Figure 4: Scattergrams showing correlation between connectivity and integration. The R-square value decreases with increased levels of occlusion and is affected by metric properties of the shape.

This is confirmed by the R-square value that measures the strength of a correlation, Table 1. This value decreases in general from the first to the last figure. An observation that follows from this is that as we cut into the shape we affect the relationship between what is seen locally from each point and its position in the configuration as a whole. However, in most shapes at least eighty two percent (82%) of the differences between perimeter points in terms of their connectivity values are due to their relation to every other point in the shape captured by its level of integration.

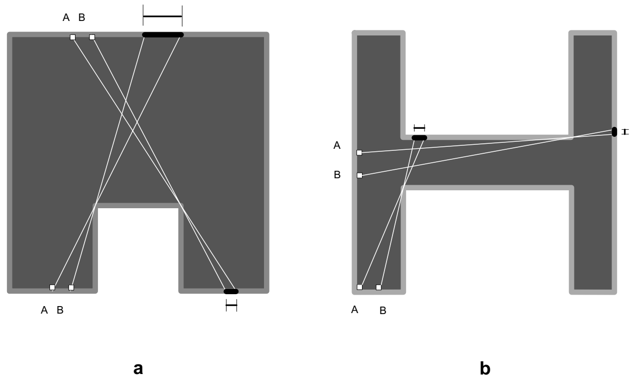


Figure 5 (a,b): Isovist radials produced from segregated (bottom) and integrated (left) points. In figure 'a' the increase in the perimeter of the isovist from the segregated positions is smaller than the increase from the integrated locations. In figure 'b' the difference between the isovist perimeters becomes smaller.

The decrease in the R-square value for figure 4i can be explained by taking a closer look at its scattergram. The points that lie below the line at the bottom left side of the scatter occupy the horizontal sides of the H shape. These points have connectivity levels that are lower than their integration suggests. The difference in the two variables is produced by the reflex angles. Moving into the area of the shape they reduce their integration levels, but they also reduce to a greater extent the perimeter length visible from those positions. This result can be more clearly demonstrated by looking at the perimeter graph for this figure, figure 3i.

We see that the peaks and the troughs in both curves occur at corresponding locations. On the other hand, the decrease or increase of values in adjacent troughs for each of the two variables are in an inverse relationship. In the connectivity graph, shown at the top, they progress from 'low' to 'lower', to 'low'. In the integration graph they move from 'low' to 'higher' to 'low'. This result shows that apart from the reflex angles, the central part of the H shape, integrates more than it connects. It also shows that the relationship between 'before' and 'after' with respect to these angles is different in one measure than in the other.

Our observations can be summarised as follows: First, there is an impact of metric properties on the values of integration, connectivity and on their relationship. Second, a poorer correlation like the one in figure 4i shows that what is strategically located in terms of global scale information does not precisely correspond to what is strategic at the local level. Third, as we affect the correlation between connectivity and integration, the sequential patterns in the transmission of information with respect to each of these properties become different from each other.

Time captured by the rhythms in the horizontal distances between the peaks has a similar pattern for both variables as they are both at their highest levels in similar locations. Time represented by the sequence of peaks and troughs has similarities in relation to the peaks and differences in the alternation of heights of subsequent troughs. Integration and connectivity can be thought as two tracks of information that are either parallel, exhibiting the same frequencies and rhythms, or partly aligned and partly contrasted, like ranges of singing voices that move into a rising direction together for certain parts of the melody while moving in the opposite direction for others.

Using the shapes in figure 6 we will now focus on the impact of metric properties in the relationship between the two measures in asymmetric arrangements. We observe that the R-square value decreases as the shapes become increasingly more complex and more hollowed out. In the last figure it drops to 0.61, a value that is close to that given in figure 4i. However, the plotted points in figures 6b-d tend to cluster along a line rather than a curve. A number of smaller clusters are also formed that cross the main regression line at a steeper angle indicating that for these locations connectivity is stronger than integration, something that will be discussed later in greater detail.

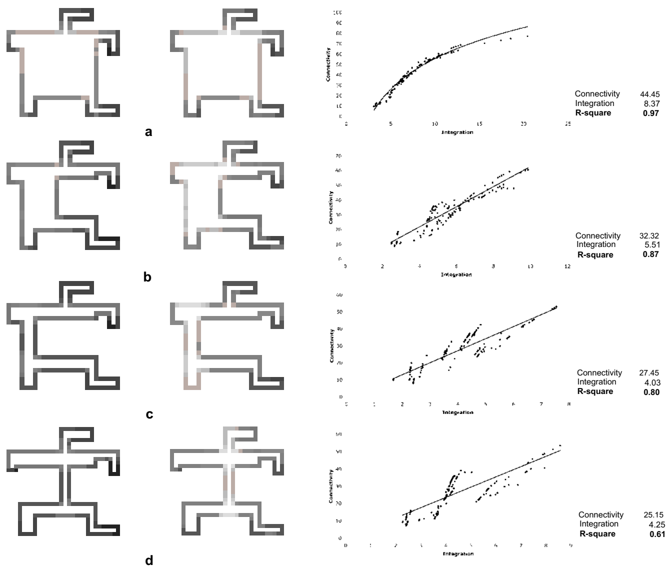


Figure 6: Connectivity and integration in irregular arrangements.

Figures 7a-c are variations of figure 4i produced by adding a third component of progressively decreasing perimeter length to the H shape Examining the data we observe that the decrease in the length of the vertical components results in an increase of connectivity and integration values. From figure 4i to figure 7a the R squared value drops, while from figure 7a to figure 7c it increases dramatically to an almost perfect correlation. In figure 7a the connectivity values of the three vertical components of the shape rise disproportionally to their integration levels. In the other two shapes they retain a good relationship with where they stand in relation to the rest of the system.

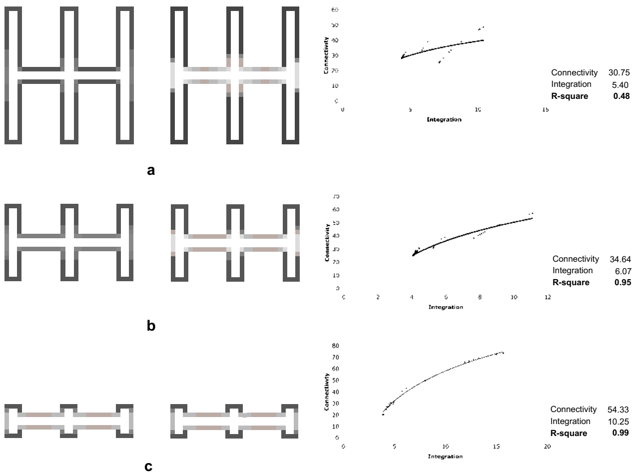


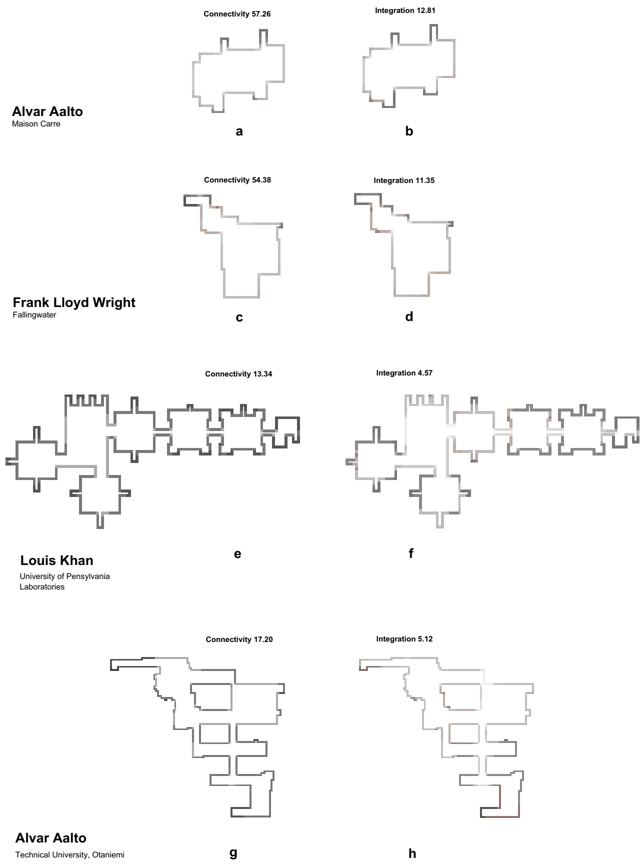
Figure 7: Metric transformations of shapes

These results confirm the impact of size on the ways in which parts relate to the whole. Looking at these figures as two dimensional configurations we see that the metric variations affect the relationship between the one dimensional and the two dimensional extension of the shapes. In figure 7a the three vertical elements extend along one direction contrasting the central spine that holds them together. The decrease in their size shifts the shape balance towards the horizontal extension. The increase in the R squared value confirms this harmonising effect relating the results of this analysis with common design intuition.

Linking the observations made for figures 3a-d, 6a and 7b-c we can conclude that simple configurations, moving towards convexity[2] or linearity, tend to approach a perfect relationship between integration and connectivity or between the local and global scale. Space syntax research has associated the relationship between connectivity and integration with spatial intelligibility. This is because it captures how local parts in a layout can inform us about their relation to the entire configuration (Hillier 1996). The results of this analysis suggest that a good correlation is an indication of regularities in the rate of change, or in the temporal patterns in the transmission of local and global scale information. Looking at this rate we have observed similarities and differences between the two levels of information and for different parts of the shape. These account for the extent to which parts retain a balanced connection to the whole. The capacity of the correlation to suggest good levels of intelligibility of shape perimeter remains to be tested against more complex configurations in the section that follows.

Examining some real examples.

We now move to an analysis of some real examples. These are Aalto's Maison Carre, Frank Lloyd Wright's Fallingwater, Louis Khan's Laboratories, University of Pennsylvania and Aalto's Technical University, Otaniemy, figures 8a-h. Table 2 presents the numerical results for this sample. Maison Carre and Falling Water have the highest connectivity and integration values followed by the other two buildings. In terms of the standard deviation for connectivity values (vc-value) Fallingwater has the highest degree of differentiation (16.46) followed by Maison Carre (14.90). In relation to the standard deviation of integration (vi-values) Maison Carre (4.78) has slightly higher levels of differentiation than Fallingwater (4.43). The last two cases present the highest degree of stability having considerably lower but closely similar standard deviations for both connectivity and integration (5.36, 1.15 in Khan and 5.39 and 1.23 in Aalto).



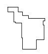
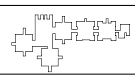
	mc-value	i-value	vc-value	vi-value	R-square
	57.26	12.81	14.90	4.78	0.97
	54.38	11.35	16.46	4.43	0.91
	13.34	4.57	5.36	1.15	0.69
	17.20	5.12	5.39	1.23	0.55

Table 2

Figure 8: Distribution of connectivity (left) and integration (right) values along the perimeter of the buildings.

Figures 9a-d show the corresponding scattergrams for these shapes.. Maison Carre and Fallingwater appear similar to the shapes examined in figures 4a-d and 7b,c in that the plotted points are tightly distributed along a curved line. As previously explained, this pattern of distribution indicates a differentiation in the rate of change of values along different sections of the curve. We see that these buildings are characterised by high degrees of differentiation both in terms of connectivity values for the entire perimeter length (v-values) and in terms of both connectivity and integration for shorter trips within the occluded and the open areas of their shape.

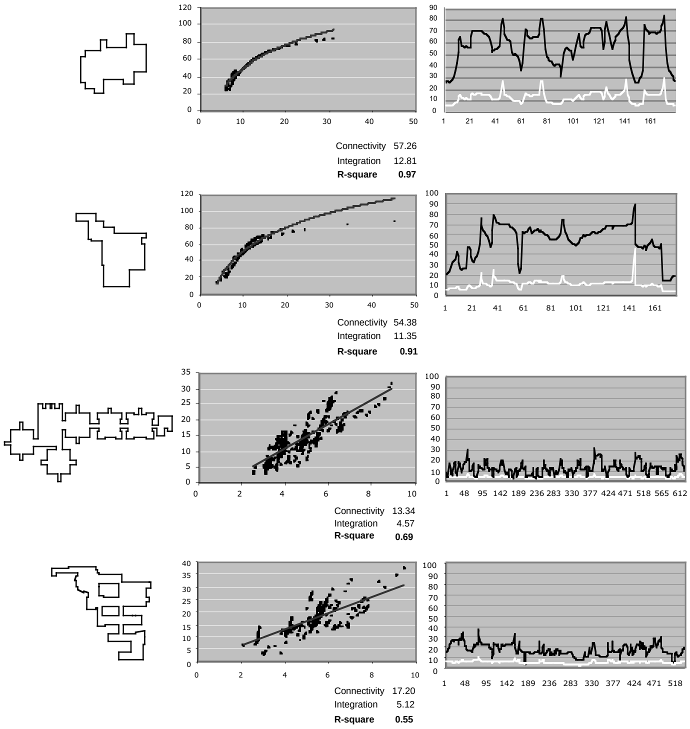


Figure 9: Scattergrams and graphs of connectivity (black) and integration (white) values.

The scatters for Khan's Laboratories and Aalto's Technical University show that the rate of change with respect to the entire sample of perimeter locations tends to stay the same as points tend to be distributed along a straight line. However, in both buildings there is a series of clusters that form linear scatters in themselves crossing the main regression line at a steeper angle. This means that for smaller perimeter sections connectivity is stronger than integration. The individual clusters in Khan correspond to the square shapes at the left, the bottom and the far right end of the configuration. In Aalto's Institute of Technology the linear clusters correspond to the four shapes on either side of the long back to front axis and to the narrow shape at the top left side of the building. These perimeter sections are experienced as separate sub-complexes that are more locally connected than globally integrated.

The intensification of connectivity over integration is based on the geometric and metric properties of these buildings. Both configurations consist of clearly identifiable shapes demarcated by reflex angles that are in close proximity to each other. This means lower levels of inter-visibility and consequently lower levels of integration. However, within these areas connectivity values are high as a result of a considerable perimeter length visible from their locations.

The R-square values indicate good levels of intelligibility in the first three cases in general. However, there is a greater extent of intelligibility in the first two buildings as their integration levels are much higher. The R-square value in Khan (0.69) suggests that connectivity is a good indicator of the global structure. However, lower levels of integration show that the global scale is overall less intelligible. Finally, in Aalto's Technical University there is less intelligibility in terms of the system as a whole and in terms of the ways in which local scale exploration guides us in the understanding of the overall configuration.

We should clarify that an evaluation of these buildings in terms of intelligibility is not complete as different kinds of syntactic analysis should be also employed for this purpose. Examining the axial structure would illuminate other important properties like the long axes that extend from one side to the other establishing global scale relations. Alternatively using a grid of both spatial and physical locations would enable us to study the ways in which the perimeter is experienced from different parts of the layouts.

Shape configuration as a notion of time

We have examined these buildings measuring syntactic properties of their perimeter. This analysis enabled us to describe them as shape and space configurations under a single analytical framework. We will now move to the second objective of this paper and explore how syntactic properties can be studied from the point of view of sequential spatial experience. To this end we produce graphs plotting integration and connectivity in a sequence, figures 9a-d. A first look at these graphs shows that Khan's Laboratories have the highest level of regularity in the whole sample. We see that the line rises and falls at similar distances on the y axis and at regular intervals on the x axis. In contrast, Fallingwater seems to possess the lowest levels of repetition. This is because it is the only example in which the graph line does not fall in low troughs in the same frequency as in the rest of the cases. These two buildings therefore, offer the most contrasting pair for comparison. For this reason our analysis will mainly focus on their graphs, figure 10a-c

If we consider each point on the x axis as being a physical location as well as a time segment in a route progressing along the perimeter, then this axis represents time as succession. The value of each point on the y axis captures its position in the configurational pattern expressed by its integration and connectivity levels. Points that carry similar weight by having similar values have a syntactic symmetry by virtue of either being at the same depth level or having the same number of connections, or by both possibilities. These points are conceptually linked together by the property of holding a similar position in the configuration. Mapping these locations on different bands defined by ranges of values that are close together, figure 10a-c we can produce a representation of frequencies of values, or of their recurrences within certain value categories expressed by the white vertical lines. These lines represent values at peaks and troughs as these account for the maximum and minimum connectivity levels in each band.

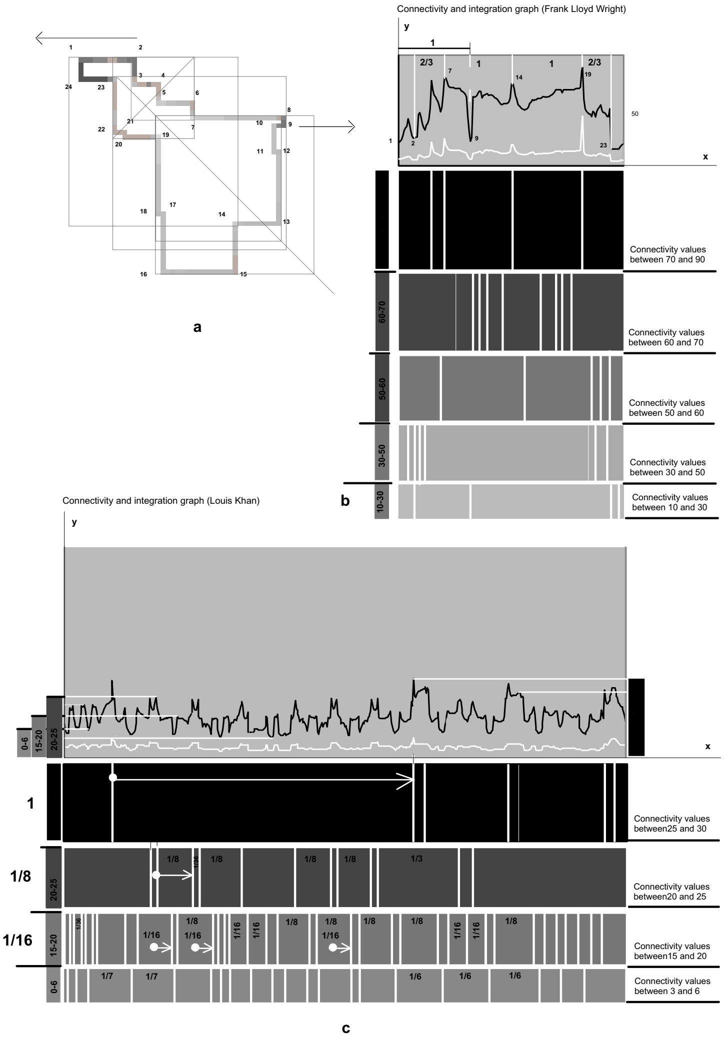


Figure 10 (a, b, c): The connectivity graphs (mapping perimeter locations in a continuous linear sequence) have been dissected into horizontal bands according to different categories of connectivity values. These values are represented by the white lines defining a sequence of non adjacent perimeter positions in each band.

This kind of representation captures the following: First, a categorisation of syntactically symmetrical elements into groups expressed by the horizontal bands. Second, a number of recurrences of these elements represented by the number of lines within each band. Third, the patterns of sequences of similar values mapped by the horizontal distances between subsequent lines, or the periodic structure of their recurrence. Finally, the ways in which these sequences relate to each other expressed by the time required for their lines to repeat, or otherwise their period.

This graphic representation disassembles value categories from the original sequence and re-orders them into higher order sequences according to syntactic similarity. We can propose that this representation captures time as a notion of order. This is because it records patterns holding elements together beyond physical proximity or beyond the linear sequence in which they are seen. We can study time as order in two ways: First by looking at the frequency of elements that carry similar syntactic weight in the configurational pattern. Second, by examining the distances between these elements or the length of time travelled between positions of syntactically equal weight.

We should clarify that as the original sequence on the x axis is defined by an assumption of a peripheral route, different routes could be also studied. These can be defined according to building use, or occupation patterns, or actual routes people take in layouts. In this analysis we will concentrate on the hypothetical path we have defined only, which in real life situations might be close to a route along surfaces in gallery rooms. We will also mainly focus on connectivity values. This is because the two variables have a good correlation, falling and rising at similar positions, so that observations made for the one can also account for the other. The difference in the rate in which the variables change as indicated by their scatters forms a subject of further investigation to be addressed by research in the future.

Comparing figure 10b with 10c we see that there are four sequences in Khan and five sequences in Fallingwater. Moreover, there is a greater extent of frequency of values within each band in the former than in the latter. Therefore, Khan's Laboratories are characterised by a greater deal of occurrence of identical values and over a larger number of perimeter points. Recurrence of a syntactic symmetry can be seen as an instant of 'temporal symmetry', in the sense that an identical pattern repeats in time. In this respect, the shape perimeter in Khan is experienced through a great extent of temporal symmetries linking together a large number of elements that have a low value and therefore, a weak position in carrying information about the relationship between the parts and the whole.

We now move to examine the sequences of intervals in each band. Starting with Khan, we see that there is a periodic structure of horizontal distances that possesses a certain level of regularity in all bands. In Fallingwater the only pattern observed concerns the symmetrical positioning of the third line in the first band with respect to the two lines on its other side. In Khan a syntactic symmetry in terms of identical values is combined by a strong regularity in terms of the lengths of time travelled between them. In Fallingwater the temporal structure is weaker as there are fewer repetitions of values and almost no regularity in their re-appearance.

In order to examine the relationship between the periods of different series we need to define the unit of measurement. If this is taken as the widest interval of the first series we see that in Khan as the first line in this series moves to its second position covering a distance of 1, the first two lines in the second series move together for a distance of 1/8, while the first two lines of the third series cover a distance of 1/32. For the largest part of the third series the two lines move for a distance of 1/16. Thus, for the first three bands of values the periodic cycles decrease in a regular way showing that their movement, is proportionally phased like three pulses or three music notes each of which is repeated for a time that is a proportional fraction of the time it takes for the others to repeat[3].

Therefore, there is a strong correlation between the values in each band and the period of their cycle in the sense that every time a value increases the distance travelled between subsequent values in the same series becomes longer. In Wright there is no particular pattern in the relationship between values in different bands as they consist of unrelated sequences, figure 10b. However, a closer look can reveal some local symmetries embedded into their asymmetric arrangement. The second line in the fourth band is at a distance of 2/3 from the second position of the line in the first series (see the marked distances at the top of the graph). Similarly the third line in the last band is at the same distance (2/3) from the last line in the first sequence. Five values in different ranges are thus, disposed according to a property of bilateral symmetry with respect to distances or timing of their occurrence. Looking at figure 10a we see that the high values correspond to the three reflex angles situated in the large open area of the shape, (marked as 7, 14 and 19), while the low values are represented by two other reflex angles in the top right part of the perimeter, (indicated with the numbers 2 and 23). This observation points at an emerging diagonal axis of 'just about' symmetry that is partly implied by the distribution of colours, and partly buried behind the irregularities in the perimeter of the shape.

Another observation concerns the relationship between the highest peak and one of the lowest troughs corresponding to the points marked on the graph as 19 and 9 respectively. Their values are in a strong asymmetry in relation to each other as they are at the extreme opposites of the connectivity scale. The distance of point 9 from the lowest trough to its left side, point 1, and the distance of point 19 from the highest peak also to the left side, point 14, are equal.

The syntactic asymmetry between the two pairs of points combined with the symmetry of intervals in their respective sequence shows that they are in a relationship of 'reflected synchrony', like two persons simultaneously moving away from a line in opposite directions. In terms of their position in the shape, point 9 and 1 are in the deepest recesses of the perimeter, while points 14 and 19 are situated on the two reflex angles in the large area of the shape. The temporal pattern in the relationship between the two pairs of points captures a symmetry in the directional movement of the reflex angles and the recessed corners, the former moving along two diagonal axes inwards, the other progressing along an horizontal axis outwards and in opposite directions.

With these observations we can reach our conclusions for the two buildings. The part of the analysis that dealt with shape configuration as a timeless notion showed that Fallingwater is characterised by strong levels of integration and strong levels of differentiation both in terms of the perimeter as a whole (v-values) and in terms of the rates of change within low and high values (scatters). The analysis that dealt with configuration as a notion of time showed that there is also a high level of differentiation in the pattern of its transmission. Results also showed that in Khan there are lower levels of integration and connectivity, a less tight relation between the two and a high degree of stability of perimeter locations. In terms of the configuration as a temporal pattern the analysis indicated high levels of regularity or otherwise a stable temporal pattern of information.

Before moving to our final conclusion we discuss the theoretical dimensions of the ideas presented in this paper. Intelligibility as defined by space syntax research is based on the relationship between global and local configurational properties. These can account for how simple or complex a layout is from a particular location and what is the kind of experience at a local level with reference to the global scale. By looking at the transformation of local and global properties from different parts of a layout intelligibility already incorporates the notion of time as a sequence between different states. However, it approaches spatial description as a totality or as an absolute notion describing relations amongst elements independently of the temporal sequence in which they are actually seen.

The notions of configuration and time in general are diametrically opposed. One is an absolute concept describing abstract relations amongst elements, while the other is a relative and dynamic entity consisting of a number of states in a sequence. However, at the level of real experience time is the carrier of configuration. Different kinds of realities relate the two notions in different way, often giving predominance to the one over the other. In the visual arts, or when looking at two-dimensional shapes, configuration takes over time by virtue of being immediately accessible. We may say that we see paintings or shapes instantly, meaning in a very small fraction of time, but in reality, provided that we account for one painting or one shape only, we see them within a time that is almost uniform in its context. This is because there is no 'before' or 'after' that particular instant to establish the notion of temporal succession.

In architecture, discontinuities in what we can see break both configuration and time into separate states. Configuration becomes captured in a web of time that unfolds serially. However, it also contrasts the linear motion of time by re-ordering its events or its visual fields into higher order patterns and higher order time sequences. It was explained how syntactic symmetry or regularity in its occurrence link different temporal moments outside their positions as successive states. This re-ordering of events is what creates the encounter between a synchronous (configuration) and a diachronous notion (time). The field of their encounter is both static and dynamic. Static because it is about abstract patterns locally observed, like syntactic symmetry, and dynamic because it is in a process of reorganising these patterns into higher order relations as new information becomes available.

We can therefore reformulate the definition of both time and configuration in architecture and suggest that neither of the two is an absolute or a sequential notion, a totality or an accumulation of individual instances. They both consist of relations amongst contiguous elements that unfold in sequence and relations that operate across distance. Configuration can be thus, approached as a description of time properties and time as a description of configurational patterns. This analysis has showed that by studying the ways in which configuration unfolds in time or the ways in which the temporal structure exposes configuration we may begin to capture subtleties in the description of both levels. We may also begin to describe the actual subject of their structuring, i.e. spatial experience.

A final remark concerns the relationship between this analysis with an analytical context concerning mathematical proportions in architecture. Traditionally, studies of form have focused on harmonic ratios amongst architectural elements and their isomorphic correspondence in music (Wittkower 1967). This study has attempted to develop ways in which the study of rhythm, symmetry and differentiation can be applied to patterns of visual fields expressed as syntactic properties of shape perimeter. In this way, it might provide a foundation to extend the mathematical analysis of architecture from the 'surface' level of architectural elements to the 'deep' level of syntax.

Conclusion

This paper does not attempt to provide a general approach that solves fundamental problems of shape, space and time but to explore ways in which the three notions can be linked together. Measuring properties of shape perimeter it uses methods for studying shape configuration without relying on traditional definitions of geometrical order. Looking at configuration as a temporal pattern it tries to study the ways in which it enters our experience. We acknowledge that these methods are at an embryonic level and that further research is required to validate their findings. It is hoped that they might offer an alternative and systematic way to approach conventional notions like symmetry, balance, and rhythm that have dominated the intellectual history of formal description in architecture.

Acknowledgments

This paper is dedicated to the memory of my colleague Dr Tadeusz Grajewski who contributed to the early development of the ideas presented here.

Notes

1 The isovist tool was initially developed by Benedict and is defined as a polygon area visible from a vantage point in space (Benedict 1979)

2 A convex space is defined as a space in which any two lines can be linked without crossing its boundaries (Hillier and Hanson, 1984)

3 This pattern is akin to the proportional time value system employed in musical notation, i.e. a semibreve (1), a quaver (1/8) and a semiquaver (1/16). We do not suggest that the analogy of the proportional structure of the perimeter with musical time values was intended by the architect. The example of musical notation is used to simply illustrate the role of time in other serial forms of art.

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