Describing Shape and Shape Complexity Using Local Properties

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Abstract
Notions of shape and the design of space in architecture are inextricably linked together. Analytic developments of shape and spatial organisation have been based either on systems of geometric order or on systems of interrelated units of space. In this paper we explore ways for quantifying shape without relying on reductive concepts of geometry or on elementary spatial segments. This is attempted by measuring local characteristics of shape perimeter. Simple configurations are described by measuring degrees of stability and differentiation operating at the level of a set of perimeter points as well as of succeeding perimeter sections. In more complex shapes the quantification of these concepts is not yet properly addressed. However, it is possible that the ideas discussed here may contribute to a future development of a generalisable analytical approach.

Keywords:
shape, geometry, perimeter, complexity

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Shape as a perimeter configuration

As we move inside buildings we receive information and experience changes depending on our position in space. However, what we see as a number of sequential visual fields has a synchronous nature offering a stable framework to the changing spatial experience. This framework relates spatial moments into formal structures outside the actual spatial terrain. A simple example of such a framework is the perimeter of a building configuring its overall shape.

The distinction between what we see in space, and what we grasp by looking at a formal pattern on a plan, is made by a number of authors. Colin Rowe's account of Corbusier's Villa Stein underlines the difference between the symmetrical structural grid and the asymmetrical organisation of its interior space (Rowe 1984). The effect of a building's perimeter to the understanding of its overall shape is discussed by Rowe, in a comparison between Corbusier's Palace of the League of Nations and Gropius' Bauhaus in Dessau. A frontal disposition of perimeter boundaries in relation to approach routes in the League of Nations aids the intelligibility of the buildings' overall shape. In contrast, the meandering perimeter of the Bauhaus lends itself intelligible only when seen from the air.

Earlier references to the distinction between experiencing space and understanding its shape are found in the work of Frankl (1914). For Frankl the synthesis of partial images received from different spatial points leads to a retrieval of a single image, the conceptual framework of a building's shape. Arnheim makes a similar proposition suggesting that there is no direct relationship between what the eye sees and what a building is, as only partial amounts of information is available from each spatial position (Arnheim 1977). Peter Eisenman's analysis of Terragni's work underlines the importance of formal relations in linking direct observation to 'deep' shape structures (Eisenman 1971).

The description of spatial experience is the main focus of 'space syntax', a theory and a method for measuring spatial properties and relating them to patterns of movement and social function (Hillier and Hanson 1984, Hillier 1996). Layouts are described as permeability patterns held amongst 'convex spaces' and 'axial lines'. Fundamental in the convex and axial representation is the disposition of boundaries and shape properties of a plan. However, beyond the starting point of convex partitioning and axial linking of space, space syntax moves away from descriptions of shape, focusing on permeability relations of layouts.

Another tool for representing spatial environments is known as isovist, defined as a polygon shape visible from a vantage point in space (Benedict 1979). The practical limitations of this tool in terms of drawing isovists from all possible spatial points have been overcome by recent developments at UCL. These have replaced convex and axial lines with an isovist map constructed at a grid of locations (Visibility Graph Analysis). Space syntax measures of a graph are calculated considering interconnectivity relations amongst isovists (Turner and Penn 1999). In this way, every isovist is given a mean depth value quantifying its accessibility to all other isovists in the configuration. Visibility graph analysis is applied on buildings and urban layouts, and correlated with patterns of movement. The major thrust of this tool is a description of spatial properties at a fine level of detail. However, up to the present, it seems to give secondary consideration to the structure of shape and to the ways in which it contributes to our understanding of space.

A shift from space to shape properties characterises the analytic developments at Georgia Institute of Technology (Peponis, Wineman, Rashid, Hong Kim, Bafna, 1997). Peponis et al. identified spatial units within which visual information regarding corners, edges and surfaces is informationaly stable (s-partitions and e-partitions). In simple layouts these units tend to expose the whole configuration at once including the defining boundaries of shape and space. In more complex layouts the pattern of distribution of s-partitions and e-partitions begins to suggest the extent to which shape properties of the layout as a whole can be grasped as we move in space. The significance of this method is its ability to map areas of information stability and change with regards to shape elements on a plan. In this way, the description of spatial experience encompasses shape 'constants' bridging the gap between the changing nature of a spatial environment and the constant nature of its shape.

However, tools of convex partitioning of space examine built shape from bottom-up. It seems interesting to examine whether shape can be approached in a reverse way, i.e. starting from its perimeter before moving to its property to enclose space. The question we are trying to answer is: is it possible to describe shape based purely on the syntactic properties of its perimeter? The success of this investigation depends on the extent to which it can enable us to compare shapes of different geometry without relying on traditional notions of geometrical order.

We can define shape as a configuration consisting of edges and corners defining a continuous perimeter line. In a convex shape any two points along the perimeter can be joined together by lines that belong entirely to its area, fig 1a.

In fig 1b the lines joining certain points either cross the perimeter or lie outside the shape. These observations lie at the core of the conventional definition of convexity. However, the suggestion we make is that each perimeter location has a mean connectivity value (mcv) defined as the percentage of locations that is connected to without crossing a boundary or falling outside the area of the shape. By measuring local properties of shapes expressed as a structure of connectivity connections we may begin to understand how simple configurations behave. Furthermore, if we consider shapes as enclosing space, it is interesting to know how local properties of perimeter articulation can account for spatial experience as a sequential process.

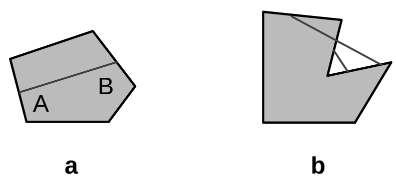


Figure 1. Convex and concave shape relationships between perimeter positions

Fundamental as this observation is, we can begin to describe shapes as the average of connectivity values distributed along their perimeter line. The perimeter in fig 2 is represented by a set of square units joined facewise. This is considered as a graph where each square is linked to other squares according to the rules mentioned above. A GIS based computer programme developed at the Welsh School of Architecture calculates a number of measures, the simplest of which is connectivity value for each square and for the system as a whole. Results are represented on an absolute scale of shades of grey employing ten bands of equal range from the lightest shade of grey (90-100% connectivity value) to black (0-10% values). We recognise that 0% is an impossibility, whereas 100% is possible only in convex shapes.

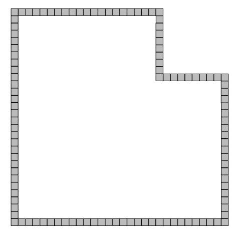


Figure 2. Representing perimeter by a set of square units

The difference between our approach and the ways in which visibility graph analysis is used is very subtle, however fundamental. While both measure syntactic characteristics of a fine grid of locations represented as a graph, our starting point is shape and its perimeter, as opposed to the space it encloses. Our underlying consideration is based on the ways in which buildings are designed, i.e. as shape configurations rather than as visibility patterns of small particles of space. Our aim is to examine how syntactic properties of shapes might begin to explain design decisions which mainly rely on conventional top-down notions of geometrical order.

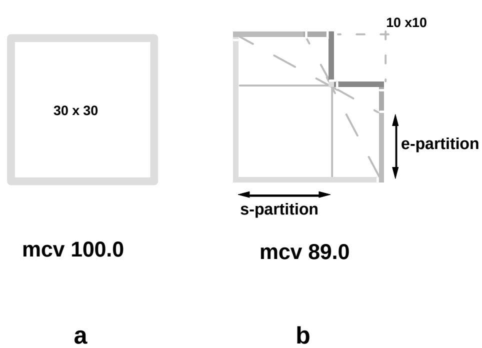


Figure 3. The distribution of shades captures s-partitions and e-partitions. (The mean connectivity values are indicated alongside).

We begin by comparing a 30x30 square with an L shape generated by removing a 10x10 unit, fig 3a,b. In the second figure the mean connectivity value drops from 100 to 89% indicating the effect of cutting into the shape and introducing inequality of connections. This figure shows that the distribution of shades captures the overlapping shape and e-partitions marked by the shift from light to darker shade of grey.

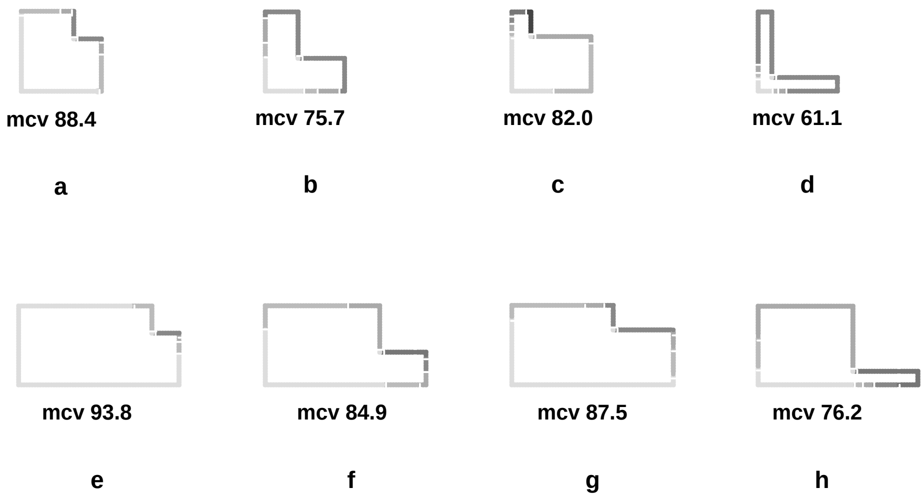


Figure 4. Metric variations of L shapes deriving from a 30 x 30 square (fig 4a-d) and their elongated counter-parts (fig 4e-h) produced from a 30 x 60 rectangle

Figures 4a-d present metric variations of an L shape deriving from a 30x30 square. We observe that mean connectivity decreases from high to lower values. The next row of figures, 4e-h, are generated by elongating the 30x30 square to produce a 30x60 rectangle but retaining the metric properties and the relative position of the removed component. In both categories of figures mean connectivity decreases from high to lower values. However, comparing fig 4a-d with 4e-h, we see that in the latter for the same perimeter of insertion we have higher mean values.

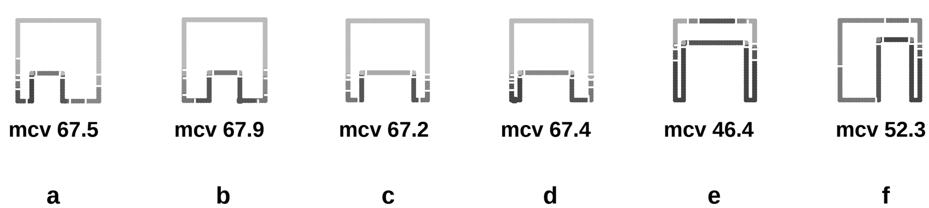


Figure 5. Metric variations of a U shape produced by removing a rectangle from a square

Figures 5a-f are metric variations of a U shape produced from a 30x30 square. Similarly to the examples examined before, progressive increase of the size of the removed component results in progressive decrease of the mean connectivity value. The symmetrical and asymmetrical variations in figs 5a,b, 5c,d show that there is a slight increase in the values from the symmetric to the asymmetric arrangement. This is because in the latter, the increase in the connectivity values of the cells on the right side of the shape is larger than the decrease of values on the left side. Moreover, the shades of grey in the asymmetric shapes have a different distribution than that in the symmetric ones, indicating the effect of asymmetry in generating differentiation in design.

Examining metric variations of a square H, provides similar observations, fig 6a-c. Finally, a comparison between fig 4, 5 and 6 shows a general decrease of values from the square L to square H. These results simply confirm what common sense suggests: First, as we cut more into a shape we reduce the levels of interconnectivity of its locations. Second, metric change and symmetry seem fundamental as they determine the configurational properties of shapes, something that we will discuss later in more detail. .

mcv 71.9 mcv 52.0 mcv 39.2

a b c

Figure 6. Metric variations of a H shape

Shape as a concept of stability and differentiation

The bar charts in fig 7a-d show the distribution of values for the L shapes (fig 4a-d) from 0 to 100% connectivity divided into 10 bands. In fig 7a there is a concentration of cells at the top end of the scale, whereas in fig 7b and d the values cluster towards the lower end. In fig 7c there is a more even distribution of cells across different bands. From these we can observe that in fig 7a, b and d there is a great degree of stability in terms of connectivity values along a great extent of perimeter length at the top (fig 7a) and towards the lower ends of the scale respectively (fig 7b and d). Fig 7c suggests that there is a more gradual transition of values along a perimeter.

These patterns seem to confirm the ways in which shapes are intuitively grasped either as reducible to simple configurations or as individual formations bearing little relationship to a generic shape. Arrangements characterised by concentration of values at the far right side of

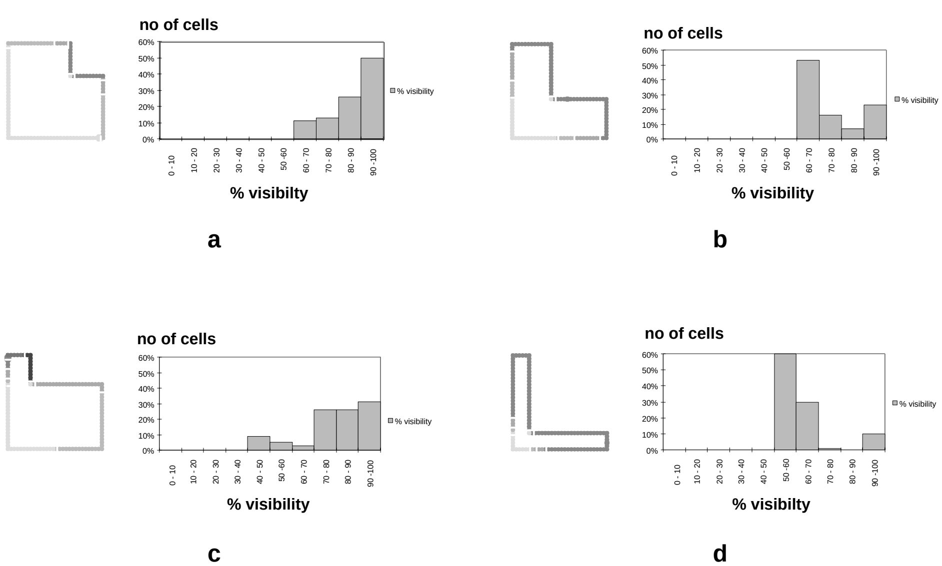
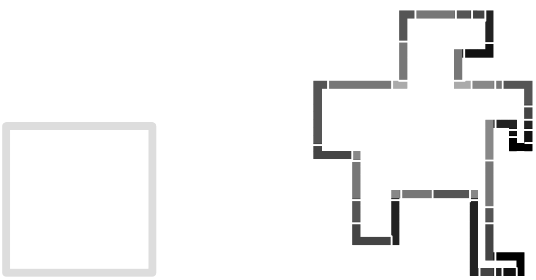


Figure 7. Bar charts showing the distribution of connectivity values divided into 10 bands

the bar chart tend to be grasped as closer to the initial rectangle, fig 4a. In contrast, those in which values cluster towards the other side, fig 4d, are less informative about how they may derive from a transformation. Finally shapes like fig 7c are seen as ambiguous tending towards both types of characterisation.

As suggested previously, both fig 4a and 4d contain high degrees of stability. Thus a second level of shape description can be based on an account of stability and change in relation to connectivity values. In this way, the difference between a simple rectangle and fig 8 is the difference between a 100% level of stability and a zero level of change, as opposed to significantly reduced levels of stability and increased levels of differentiation.

It was suggested that the distribution of greys captures those perimeter points marked by overlapping units and e-partitions mapping transitions from stability to change. A visual representation of transitions at a much finer level is provided by plotting connectivity values on a graph starting from the top left corner of each shape and moving clockwise. Figure 9 shows the graphs generated for fig 4a-d, 5a-f and 6a-c. The x-axis corresponds to the number of cells and hence captures perimeter length. The y-axis maps connectivity values. A sudden rise followed by a sudden fall of the curve corresponds to the reflex angles showing rapid change. Flat sections of the graph represent invariance. Finally, inclined parts of the curve indicate a gradual rise or fall of values.



mcv 100.0 mcv 41.9

Figure 8. The distribution of shades indicates differentiation in connectivity values and consequently reduced levels of stability

We will use these graphs as a basis to quantify patterns of information stability and change. We suggest that these patterns can be studied at two levels. One refers to the curve as a whole, while the other to segments along its course. At first we focus on the entire graph looking at the patterns of fluctuation of a curve along the vertical direction, fig 10. These account for changes in connectivity values with the top and bottom points representing maximum and minimum value within each peak and trough respectively. The level of differentiation amongst values can be calculated using standard deviation, a measure which indicates how much on average a set of values differ from a central point. High standard deviation suggests high degrees of dispersion or high degrees of differentiation amongst perimeter locations.

Fluctuations of the curve along the horizontal dimension correspond to changes in perimeter length within which connectivity values rise in peaks or fall in troughs. The distances between horizontal nodes in the graph indicate the length travelled between points of falling or rising parts of the curve. In other words, they capture the rates of change from an increase to a decrease of connectivity values. The smaller the distance between two nodes is the higher the rate of change.

To explain this clearly, let us look at fig 9a. Moving clockwise from the top left corner of this shape, we observe a gradual decline of values to the lowest position corresponding to the dark shade, a sudden rise mapping the reflex angle, a decline to low values, and finally a gradual rise to a stable position represented by light grey. In the graph we notice a difference between short and longer nodal distances indicating that the rate of change as we approach, and move away, from the reflex angle is different from the rate of change as we come towards, and move away, from the bottom left corner. We may generalise this saying that the smaller the difference amongst all nodal distances is, the more identical the rates of change between subsequent locations of high and lower connectivity values. This difference can be also

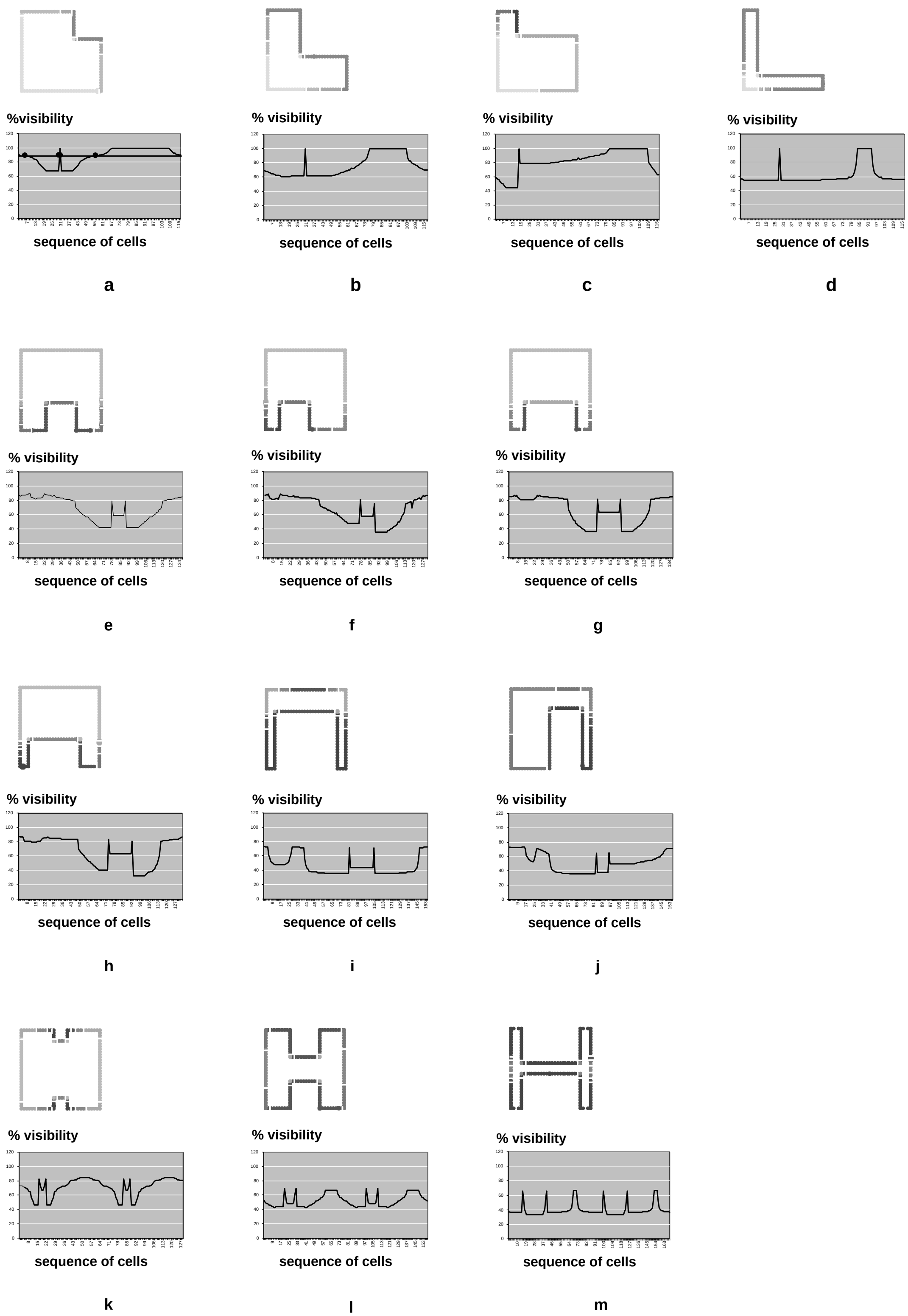


Figure 9. Graphs representing the distribution of mean connectivity values of figures starting from top left corner of each shape and moving clockwise. (The X-axis maps the sequence of perimeter locations capturing perimeter length. The Y-axis maps mean connec-tivity values).

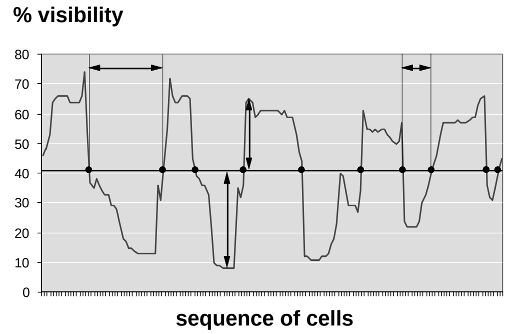


Figure 10. The vertical distances represent the distance of individual connectivity values from the mean. The horizontal distances capture perimeter sections within which connectivity values rise in peaks or fall in troughs.

measured by calculating the standard deviation of all distances between subsequent nodes, defined by the points of intersection of a curve with the horizontal line of the mean connectivity value. To overcome metric differences in perimeter length we relativise by dividing nodal distances with the total number of perimeter cells.

It should be noted that vertical standard deviation, (v-value), stands for the degree of differentiation amongst perimeter locations of a perimeter as a whole. Horizontal standard deviation (h-value) accounts for differentiation in the rate of transformation of connectivity values along subsequent perimeter sections. If we consider shapes as enclosing space which is not subdivided by internal partitions, these measures account for changes experienced gradually as an observer moves along the periphery.

Table 1 presents numerical results for the figures examined in fig 9. We see that from a to d, v-value increases in general. In subsequent figures there is a decrease in this value. Thus as the levels of occlusion, generated by reflex angles are strengthened, shapes move away from undifferentiated configurations. However, further increase of occlusion creates a large number of locations with much lower and equally distributed connectivity values. This redistribution of interconnectivity relations affects v-values, introducing stability at the bottom range.

In terms of h-values, there is a general decrease from the top to the bottom of the table with a marked decline at the very end. This seems to be also an outcome of occlusion. From the first to the last figure, the distances between succeeding points of maximum and minimum information become increasingly similar, an effect accentuated by geometrical symmetry. From these observations we can conclude that great levels of meandering and symmetry result in stability along both directions, incorporating less variation and more repetition.

	v-value	h-value
a	12.0	23.8
b	15.3	16.1
c	16.3	21.0
d	13.7	20.3
e	17.1	18.6
f	17.5	19.5
g	18.8	18.0
h	18.9	18.0
i	13.2	13.4
j	13.3	17.4
k	12.2	9.9
l	8.7	6.2
m	8.6	5.5

Table 1

The impact of symmetry and metric scale on shape configuration

We have examined the ways in which certain shapes behave in terms of connectivity relations and their degrees of differentiation and stability. We now move to consider the ways in which geometrical and metric characteristics affect the distribution of these properties. In this way, we may begin to account for how syntactic properties of shapes can inform design decisions.

Figures 11a-e present a series of experiments produced by adding L shapes of progressively increased perimeter length to a 30x30 square. Figures 11f-j derive by retaining the metric properties of the L shapes constant, while reducing the size of the initial square. We should note that fig 11e and 11f are identical but repeated to provide a symmetrical number of metric transformations from fig 11a to fig 11j. The numerical results of this analysis are shown in Table 2.

Examining the data we observe the following: First, mean connectivity values decrease with metric transformation. Second, in fig 11a-e v-values and h-values behave in opposite ways, i.e. the former become lower, while the latter progressively higher. In fig 11f-j both v-values and h-values become successively lower. The impact of metric changes on v-values and h-values can be seen clearly in fig 12a-d. These present correlations between perimeter length, v-value and h-value for figs 11a-e and 11f-i respectively.

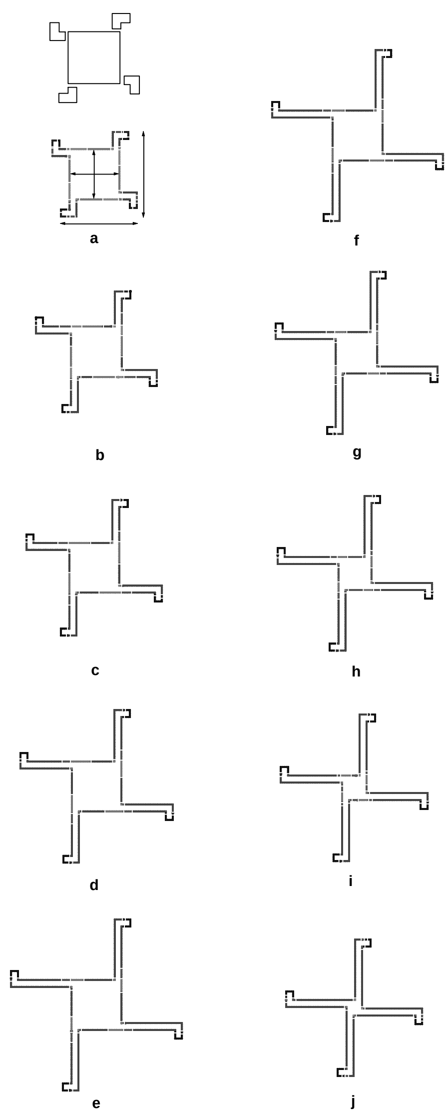


Figure 11. Figures 11a-e show transformations deriving by adding L shapes of progressively increased perimeter length to a square. Figures 11f-j derive from figure 11e by progressive decrease of the square in the middle.

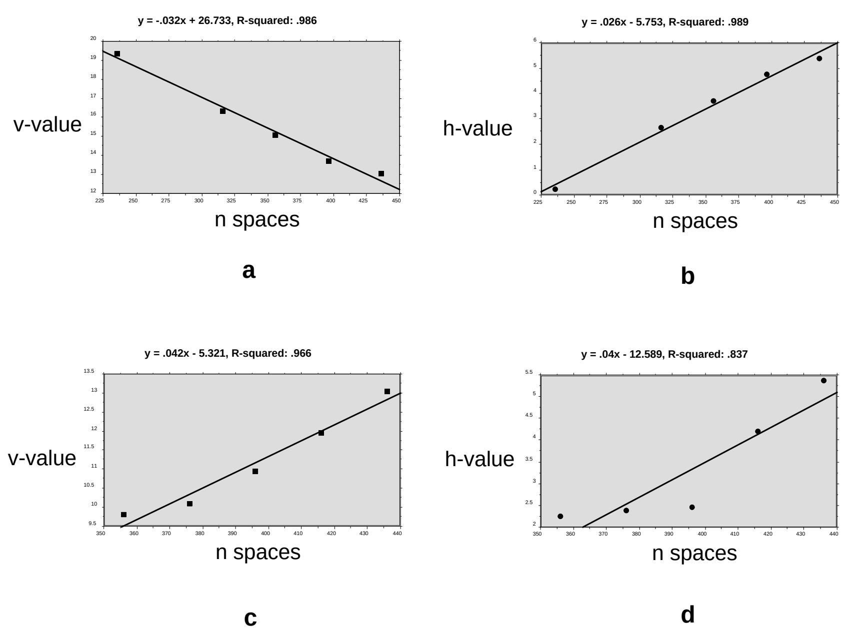
We see that metric change has an impact reducing v-values throughout the sample. In fig 11a-e it results in increasing degrees of differentiation in the rates of change in connectivity values associated with subsequent perimeter spans. In contrast, in fig 11f-i there is reduced variation in terms of these rates. In this category of shapes there is less differentiation at the level of the perimeter as a whole as well as at the level of adjacent perimeter segments. In this respect, metric transformations in the first five examples produce shapes that become gradu-

Figure	Length	mcv	v-value	h-value
11a	236	40.6	19.36	2.3
11b	316	33.6	16.32	2.67
11c	356	31.5	15.07	3.69
11d	396	30	13.69	4.75
11e	436	29	13.05	5.37
11f	436	29	13.05	5.37
11g	416	27.59	11.95	4.19
11h	396	26.27	10.95	2.45
11i	376	25.21	10.09	2.39
11j	356	26.47	9.81	2.2

ally more stable in terms of the set of perimeter points as a whole, and more differentiated in terms of the rate of change along larger boundary sections. In contrast, the transformations in the last figures reduce variety at both levels.

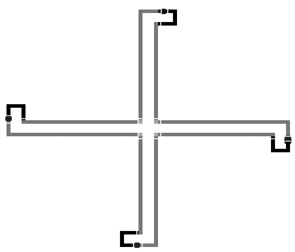
Looking at these figures as geometric configurations we see that changing the metric relationship of the initial square to its attached components, we affect the balance between the parts and the whole. For example, in fig 11a the two directional extension of the large square dominates over the two directional extension of the configuration as a whole. As the attached elements become longer, the two directional extension of the entire shape contrasts that of the square at the centre, fig 11b-e. This effect is accentuated in fig 11f-j in which the extension of the entire shape dominates further. Low v-value confirms this equalising effect linking the results of this analysis with common design intuition.

Figure 12. Figure 12a and b show correlations between perimeter length, v-value and h-value for shapes shown in figure 11a-e. Figure 12c and d show correlations for figures 11f-j.



Metric changes affect the balance between adjacent sides also. As the L shapes become longer, the extension of their long sides along one direction, dominates over the extension of the edges of the square, fig 11a-e. At the last stage of the transformation the configuration reads as eight equally sized perimeter lines converging at a focal point. This homogenising process is again picked up by decreasing h-values.

Taking the transformation process one step further, we align the long sides of fig 11j producing a cross shape with small elements attached at its end points, fig. 13. We would expect that v-value and h-values would decrease, further capturing the distribution of dark shades spread along the long sides of the shape. However, v-value increases in relation to fig 11j. This can be mainly explained by a great difference between the connectivity values along the sides, and those at the four reflex angles in the centre. This difference affects the dispersion of values from the mean, an effect that is also observed in fig 4d. Such configurations maximise the contrast between few locations providing maximum information and a large



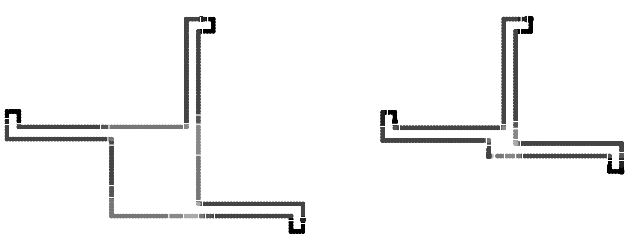
mcv		39.8
v - value	14.1	
h - value	9.2	

Figure 13. Cross shaped configuration deriving from figure11j by further reduction of the sides of the square in the middle

number of perimeter points providing more limited levels of exposure. If we disregard the reflex angles, fig 13 is the last step in a transformation process during which shapes become increasingly more homogenised and stable.

It should be noted that these results are accentuated by the rotational symmetries characterising all shapes. Figures 14a, b are asymmetrical variations of fig 11e and 11j produced by removing one of the L shape attachments. As might be expected, the mean connectivity, the v-values and the h-values increase. These results confirm common sense, suggesting that asymmetry introduces greater degrees of variety in a configuration.

These examples help to relate our analysis to design practice as follows: As we affect the metric relationship between a dominant shape and a family of subsidiary shapes, or as we vary their degrees of symmetry-asymmetry, we can measure changes in degrees of variety and repetition at the level of the entire configuration and at the local level of properties.



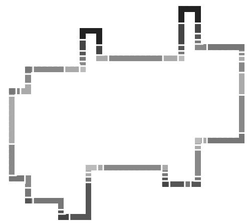
mcv			mcv		39.8
v - value	14.6		v - value	14.1	
h - value	8.0		h - value	9.2	

a b

Figure 14. Assymetric variations of figures 11e and 11j respectively

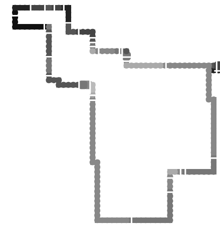
Examining some real examples

We now attempt to apply these measures to a number of real buildings. These are Aalto's Maison Carre, Wright's Fallingwater, Gehry's Guggenheim Museum in Bilbao, and Palladio's Redentore Church, figures 15a-d. Fig 15 e, f show isovists drawn on a plan of Benson and Forsyth's Museum of Scotland. We can apply the same analysis to these figures measuring properties of their perimeter.



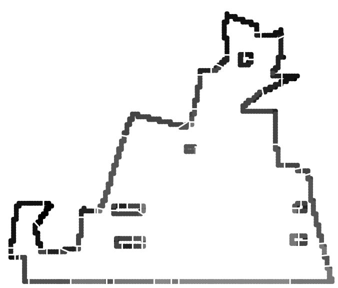
a

Alvar Aalto
Maison Carre



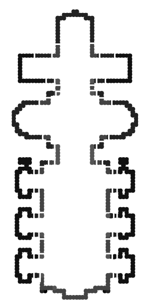
b

Frank Lloyd Wright
Fallingwater



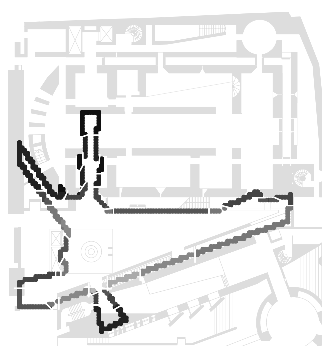
c

Frank O'Gehry
Guggenheim Museum

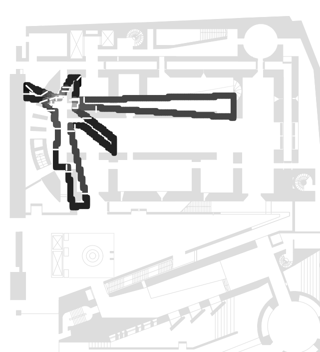


d

Palladio
Redentore Church



e
Atrium
isovist



f
Gallery
isovist

Benson and Forsyth's
Museum of Scotland

Figure 15. Distribution of connectivity values along the perimeter line of buildings (figures 15a, b and d), and two isovists (figures 15e and f). (Figure 15c is a section through the atrium space of Ghery's Guggenheim museum).

Numerical results are presented in Table 3. Maison Carre and Fallingwater have the highest connectivity values in the sample (57.3, 54.3) followed by the isovist in fig 15e (40.1). The Guggenheim museum and the isovist in fig 15f come next with significantly reduced values (35.6, 32.8). Finally, the Rendentore Church of Palladio has the lowest value (23.6). In spite

	mcv	v-value	h-value
Aalto-Maison C	57.3	14.9	3.56
Wright-Fallingw	54.4	16.4	9.7
Isovist 1-Museu	40.1	16.8	8.97
Gehry-Guggenh	35.6	14.9	8.81
Isovist 2-Museu	32.8	9	9.46
Palladio-Redent	23.6	10.1	2.55

Table 3.

of their difference in terms of geometric shape Maison Carre and Fallingwater have similar syntactic characteristics as indicated by similar values. The Guggenheim museum and Palladio's church have different syntactic properties from each other and from the ones above.

In terms of v-value the isovist in fig 15a and the first two buildings behave in roughly similar way, i.e. they have the highest differentiation amongst perimeter points from the other two cases (14.9, 16.4 and 16.8). However, Fallingwater has a higher h-value than Maison Carre indicating greater levels of variety in the rate of change along perimeter sides. The Guggenheim Museum has roughly similar degrees of differentiation with Fallingwater in spite of its lower mean connectivity value (35.6 and 54.4). Finally, the Rendentore church is the most stable configuration in the list with v-value and h-value of 10.1 and 2.55 respectively, a result largely affected by strong geometrical symmetry.

Examining the results of this analysis against the geometric characteristics of these buildings, it becomes clear that high mean connectivity value in fig 15a,b and e is the outcome of a large convex area enabling high levels of interconnectivity of locations. In contrast, fig 15c, d and f are characterised by greater degrees of occlusion that reduce the average number of connections amongst perimeter points. The high levels of differentiation amongst locations in fig 15a, b and e as indicated by high v-values is largely an outcome of the metric relations amongst the perimeter lengths corresponding to the large area and those defining the smaller parts. An increase of the former or a decrease of the latter would have an equalising effect removing differentiation from the configuration. This characteristic is found in Palladio and the isovist in fig 15f where equal length of perimeter sides defining equally occluded areas result in low levels of differentiation amongst perimeter locations.

Fallingwater, the Bilbao museum and the second isovist in the museum of Scotland, (figs 15a, c and e), suggest greater degrees of differentiation in terms of both v-value and h-value than the rest of the case studies. It is interesting to note that they all lend themselves available to direct observation in the context of spatial experience, as there are few or no internal divisions.

At this point we might suggest that the three measures discussed here can capture three characteristics in shapes. Mean connectivity value can account for the level of occlusion or break up in a configuration. The higher this value the less occluded a shape is. V-value expresses the balance between the parts and the whole. High values represent a configuration in which a dominant shape is balanced against subsidiary shapes attached to it. Finally, h-value stands for the level of repetition or rhythm characterising the linear progression along individual sides. The higher the h-value the less repetitive a pattern is. In this way, we may begin to explain characteristics like fragmentation, differentiation, repetition, rhythm, that are commonly used by designers but have always held a qualitative rather than a quantitative description.

With the discussion of building cases we conclude our observations of local configurational properties of shapes. It should be noted that it is not our intention to arrive at an evaluation of the buildings discussed above in terms of their degrees of similarity and differentiation as this paper clarifies only few amongst their numerous aspects.

It is evident that applying this analysis to more complex arrangements like those seen in fig. 16a-d, results in low values both in terms of connectivity and its two measures of dispersion (v-value and h-value). In these cases global measures of interconnectivity of locations would seem more appropriate. From this point of view the development of an analytical foundation for comparing across a larger sample of shapes, still remains a subject for further development.

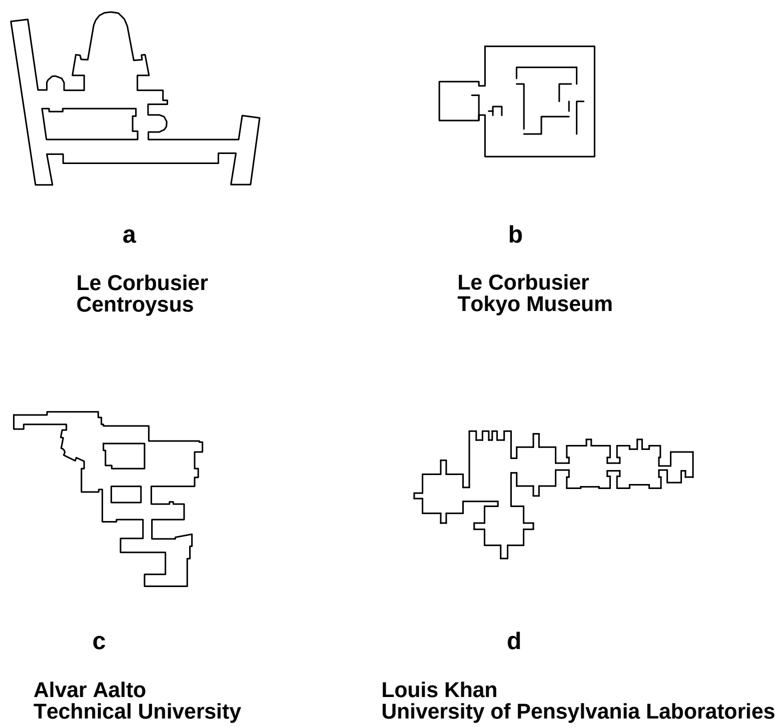


Figure 16. Four building perimeters

This observation leads to the last ideas we want to introduce. First, layouts like Fallingwater tend to reveal shape properties of the building as a whole. In this case, the concept of h-value can account for changes in the rate of information encountered sequentially by a peripatetic observer that walks along the perimeter. It is interesting to note that h-value can be translated into a concept of differentiation in the amount of time during which a viewer experiences a shift from high to low connectivity values. We can therefore say that similar times frames between high and low levels of information might be experienced by a viewer, when h-values are low. In contrast, fluctuations in the experience of time (from long to short) are expected to occur when h-values are high.

Second, a description of finer levels of perimeter meandering often observed in isovist shapes can be captured by an examination of values of adjacent cells. The importance of the way in which individual successive points behave can be demonstrated by the distribution of values in fig 13 and fig 4d in which we observe a sudden transition from dark to light shades of grey. By measuring the 'average step difference' in connectivity values between adjacent cells we can describe changes occurring on a step by step basis. Shapes like fig 17 are expected to produce graphs with fine degrees of meandering along certain sections of the curve, while still retaining high degrees of stability and the dominance of the two directional extension of the large shape.

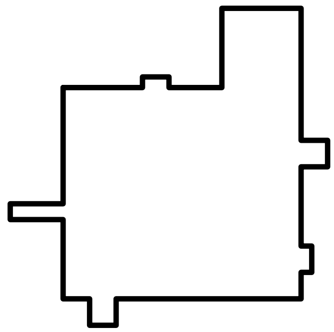


Figure 17. The predominance of the two directional extension of the shape as a whole is combined with fine degrees of local scale meandering

Third, by applying this analysis to spatial configurations using a fine grid of both spatial and physical points we can explore the degrees of stability and change for the perimeter of isovists corresponding to each grid location. This may lead to a comparison of isovists shapes along a selected route and to their patterns of similarity and difference unfolding gradually in space.

Before moving to our conclusion, we discuss the theoretical implications of the ideas presented by this paper. Inherent in space syntax analysis is the notion of sequential experience as we know how simple or complex a layout looks from a particular location and what is the kind of experience at a local level with reference to local and global measures. Neverthethrough the concepts of stability and change and that these are copresent to greater or lesser extent, at both simple and more complex configurations. At the level of more complex spatial layouts subdivided by interior surfaces, the development of an analytical foundation accounting for shape properties, requires further investigation.

Conclusion

This paper has not tried to solve substantial problems of shape and spatial configuration, but to consider these issues using a single analytical framework and a limited sample of shapes. By measuring local properties of shape perimeter, it has identified ways in which shape can be defined as a pattern of stability and differentiation. Within its context of examples, it can assist in an understanding of shape beyond conventional characterisations of geometric order.

We would like to clarify that at present our software has limited computational capacity. For this reason we have analysed only a limited number of cases. It is hoped that future software developments will overcome this problem and address the research questions against a larger sample of shapes.

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