
Urban texture and space syntax: some inconsistencies

Carlo Ratti

School of Architecture and Planning, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA; e-mail: ratti@media.mit.edu

Received 13 March 2003; in revised form 25 May 2003

Abstract. This paper reports on a number of inconsistencies that appear in space syntax—a well-known technique of urban analysis—when dealing with certain geometrical configurations. At a simple level, the analysis of regularly gridded urban textures (such as Manhattan's) reveals the difficulty of accepting the claim that space syntax allows the modelling of pedestrian choice making. In more complex cases, the distortion of two ideal textures produces a topological discontinuity, leading to the unacceptable situation where one single urban configuration produces two conflicting outcomes when analysed with space syntax tools. Several other points are also discussed, such as the difficulty of space syntax to take into account building height and land use, and its sensitivity to boundary conditions. Conclusions seem to suggest that the topological representation of cities, on which space syntax is based, discards precious metric information and is rather limiting. It is envisaged that with current increases in computational power new algorithms might allow a deeper understanding of urban texture, based on the full exploration of its metric and topological properties. This would contribute to answer the fascinating question which space syntax has helped to frame: what is the influence of urban configuration on social life?

1 Introduction

A well-known aphorism by Winston Churchill goes “We shape our buildings, and afterwards our buildings shape us.”⁽¹⁾ A comparable belief in the influence of buildings—and more generally of the built environment—on humans is common in architectural and urban thinking. It has given rise in the past centuries to several utopias that aimed at reforming society through the amelioration of design: from the visionary proposals of *cités idéales* by Claude-Nicholas Ledoux in the 18th century to the technological megastructures sketched by Buckminster Fuller in the 1960s with the slogan “Reform the environment, stop trying to reform the people. They will reform themselves if the environment is right.”

Despite all of this, attempts to quantify the interrelationship between built environment and social life are rare. A notable exception is *space syntax*, a nondiscursive theory of architecture which originated some twenty years ago in the work of Hillier and Hanson (1984) and has since been developed at the Space Syntax Laboratory at University College London, and at its various affiliates throughout the world.

Space syntax is based on the use of computer techniques to analyse urban configuration. In the words of Hillier et al (1987, page 363):

“Space syntax...is a set of techniques for the representation, quantification, and interpretation of spatial configuration in buildings and settlements. Configuration is defined in general as, at least, the relation between two spaces taking into account a third, and, at most, as the relations among spaces in a complex taking into account all other spaces in the complex. Spatial configuration is thus a more complex idea than spatial relation, which need invoke no more than a pair of related spaces.”

⁽¹⁾ Churchill is reported to have used this statement twice: first in 1924 at the Architectural Association in London, then in 1943 when requesting that the bombed-out British Parliament be rebuilt exactly as before. The quote appears in Brand (1994).

Various measures of urban configuration are correlated with aspects of social life. In its initial form, space syntax focused mainly on patterns of pedestrian movement in cities. This has subsequently been extended to a number of other aspects, such as modelling urban traffic, predicting air pollution levels, assessing the occurrence of burglaries in different neighbourhoods, and estimating the potential for retail development in streets (see Space Syntax, <http://www.spacesyntax.com>).

In recent years this versatile method of urban analysis started being used in simulation mode, in order to support experimentation and inform architectural and urban design. Usually, different options of a project are tested with space syntax and subsequently compared. This provides valuable feedback to designers and has already resulted in a significant portfolio of analysed projects, including major schemes by the architects Richard Rogers and Norman Foster.

However, despite the growing (and glowing) success of space syntax and the fascinating questions on the use of space that it has raised, some of its findings remain controversial in the academic community. The discussion focuses mostly on the support used for simulations: a simplified representation of urban texture in just two dimensions, which does not take into account the dimensional property of streets (later referred to as ‘metric’) but only the way they connect to each other. How is it possible to tell so many things about the urban environment with such a limited amount of information—that is, after having dismissed data such as the height of buildings and the size of streets?

Hillier (1999) argues against these questions in a paper entitled “the hidden geometry of deformed grids: or, why space syntax works, when it looks as though it shouldn’t”. Some questions, however, remain open and are reviewed in this paper.

2 Space syntax basics

Let us start with a brief review of space syntax. Major references in the field are the books by Hillier and Hanson (1984), Hillier (1996), and Hanson (1998), as well as the proceedings from the First, Second, and Third International Space Syntax Symposia held in London, Brasilia, and Atlanta, respectively. Selected papers from the symposia were reprinted over the years mainly in *Environment and Planning B: Planning and Design* and will be quoted below when relevant to the discussion.

In this section the review will focus on the most used space syntax technique at urban level, the axial map. According to Hillier (1999, page 169):

“In the study of cities, one representation and one type of measure has proved more consistently fruitful than others: the representation of urban space as matrix of the ‘longest and fewest’ lines, the ‘axial map’, and the analysis of this by translating the line matrix into a graph, and use of the various versions of the ‘topological’ (that is, nonmetric) measure of patterns of line connectivity called ‘integration’.”

How does the axial analysis work? The algorithm is simplicity itself. Imagine starting with an axial map, that is, a simple line representation of the street network made just of lines, as shown in figure 1 (the way to derive an axial map from a piece of urban texture will be discussed below). Then select a line (a street) as a starting point. This line will be intersected by a number, n , of other lines, which are labelled depth 1. Each of these n lines will then be intersected by m lines, which are labelled depth 2. And so on.

In other terms, each line in the map is numbered according to how many changes of direction separate it from the starting line. This measure is generally referred to as *depth* and is a kind of distance: it represents the minimum number of changes of direction to go from the origin to any other segment in the network.

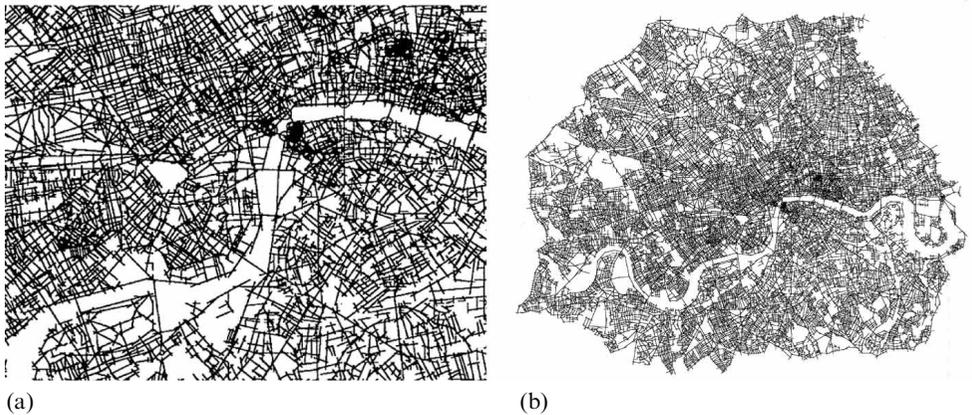


Figure 1. Axial map of London, from Hillier (1996): (a) detail of central portion and (b) overall view.

The concept of depth can be extended to *total depth*. This is the sum of all the depths in the system from a given origin. It can be interpreted as the total (or average, if it is simply divided by the size of the system) distance to go from the starting line to all other lines; in a concise form, it signals the ‘status’ (this is another name found in the literature) of the starting segment within the whole urban system

Unfortunately, the total depth cannot be used to compare the status of streets in different cities, as it is affected by the total number of nodes in the system. To take this fact into account, a relative or normalised measure is often defined, using the formula described by Steadman (1983). Beyond this formula, space syntax also uses another normalisation, based on empirical reason. The outcome of the whole process is a major space syntax parameter: the so-called *integration*.

The integration value of a line is proportional to its depth from all other lines in the network and is a sort of generalisation of the concept of average distance (it is also referred to in space syntax literature as *universal distance*). During the second normalisation process values are also inverted, in order to produce high values of integration when the total depth is low, and vice versa. In brief, the space syntax integration value represents how well integrated the initial segment is in the global system, where higher integration means more connection to the network: “The most integrated lines are those from which all others are shallowest on average, and the most segregated are those from which they are deepest” (Hillier et al, 1993, page 35).

The above process, which has been described for a given origin, can be repeated for all lines in the network. An integration value can be assigned to each of them, resulting in global integration maps, such as the London map presented in figure 2 (see over). Integration values are generally shown using a colour map from red to purple, here printed in greyscale.

Integration is the focus of the axial map analysis. The distribution of movement—both vehicle and pedestrian—that passes through each line is strongly dependent on its value: “Integration values in line maps are of great importance in understanding how urban systems function because it turns out that how much movement passes down each line is very strongly influenced by its ‘integration value’” (Hillier, 1996, page 160).

According to space syntax, this holds for vehicular traffic. In the case of pedestrian movement, integration is also the main determinant, although in very large urban systems its definition is slightly modified (it is difficult to assume that pedestrian movement in, say, Covent Garden, responds to the configuration of all of Greater London). This leads to local integration measures, which limit the calculations to the neighbourhood

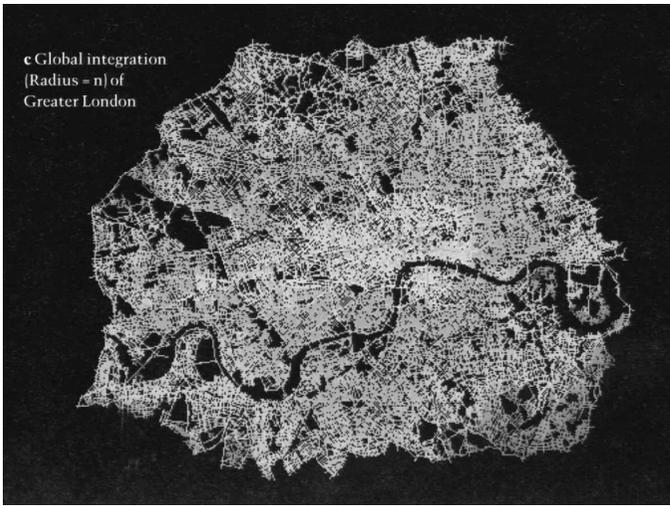


Figure 2. An iconic space syntax map of London, showing global integration values (central portions of this map have higher integration) (source: Hillier, 1996).

of each street. For instance, the so-called integration of radius 3 performs the analysis on each street by considering only the streets within depth 3.

A more general and rigorous formalism of space syntax analysis is based on the concept of graphs. Graphs are mathematical entities, whose study dates back to the 18th century and the pioneering work of Euler. A review of graph theory can be found in Harary (1972), and its use in the architectural context is contained, for instance, in March and Steadman (1974) and Steadman (1983).

Informally, a graph is a finite set of dots called vertices (or nodes) connected by links called edges (or arcs). Its value lies in the capacity it has for showing up the essential structure of a set of relationships. Its study belongs to topology, which is defined as that branch of mathematics which deals with the properties of spaces as they form connected pieces and have boundaries, independent of their size and shape. In the case of the axial map, the streets are the vertices of a graph, and their interconnections the edges; the various depth, status, and integration measures are well-established topological parameters.

From a topological stance, space syntax analysis can be considered an extension of network analysis concepts into architecture and urban planning. Its predictions about movement, however, are more controversial. The correlation of topological measures with the social use of space—namely movement in the street network—gives rise to several questions, which are reviewed below.

3 Criticism of space syntax

3.1 The topology versus geometry argument

The first concern of the newcomer to axial analysis would probably be related to its topological representation of the city, which discards all metric information. The difficulty in accepting this becomes clear when considering pedestrian decisionmaking rather than urban configuration. Convincing a pedestrian that his urban movement strategy is not based on metric but on topological distance might prove as difficult as convincing a New Yorker living on Fifth Avenue, between 111th and 112th Streets that going to Central Park North round the corner (two changes of direction in the axial map) or to Columbus Circle (a few miles away, but still two changes of direction) is the same (figure 3).

How can this be? According to Hillier (1999, page 182) “the answer lies in the hidden role of geometry”. His argument is articulated. Put simply: if a regularly structured system is considered, where all the lines in the axial map are of the same length and join each other at their extremities, then there is an identity between metric and topological measures.

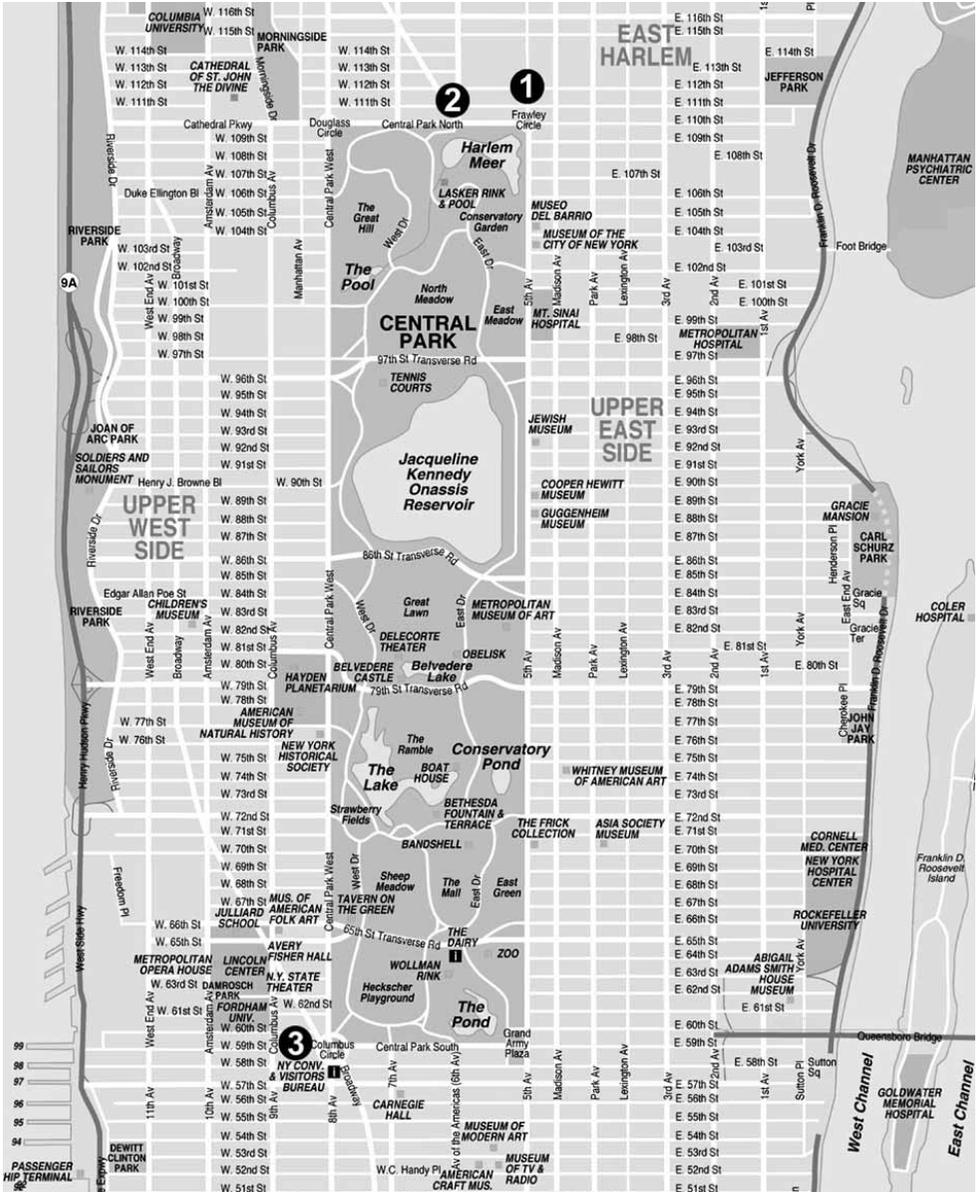


Figure 3. Map of Manhattan near Central Park. Convincing a pedestrian that his or her urban movement strategy is not based on metric but on topological distance might prove as difficult as convincing a New Yorker living on Fifth Avenue, between 111th and 112th Streets, that going to Central Park North round the corner (two changes of direction in the axial map) or to Columbus Circle (a few miles away, but still two changes of direction) is the same.

Cities are clearly more complex than regularly structured systems; their geometry is variable and irregular. However, recursive patterns are revealed: examining lines in the axial maps, Hillier (1999, page 172) notes that “the longer the line, the more likely it is to have a highly obtuse angle of incidence at (or close to) one or both of its ends. Conversely, the shorter the line, the more likely it is to have a near right angle of incidence at its end.” This “suggests some kind of consistent constructive process at work” (Hillier, 1999, page 171).

Because of these pervasive regularities, he concludes that the axial map does not ignore the geometric properties of space but *internalises* them. Therefore, its study is sufficient to provide valuable information on urban systems, and geometrical information can be discounted.

Although this argument is seductive, to be fully convincing it would require additional evidence: the hidden role of geometry in cities should not only be postulated, but supported by statistical data from a number of real cities. Would the rules apply to all of them? If not, which are the conditions under which space syntax analysis can be used?

An additional problem, of a practical order, arises when considering the applications of space syntax to urban design. If pattern recurrences are found in cities a posteriori because of their evolutionary nature (justifying therefore the rejection of all metric information), can it be assumed that they will nonetheless be present in any design option? In a Zaha Hadid masterplan, or in other extravagant and pattern-free schemes?

3.2 The axial map and building heights

The axial map discards not only metric information about the city plan, but also all 3D information. The height of buildings never appears in space syntax analysis. In fact, an underlying hypothesis is that “the influence of the grid on movement is subject to other conditions being satisfied: that the grid is more or less equally loaded in its different parts with buildings, that is, with origins and destinations, and that movement can be from all origins to all destinations” (Hillier, 1999, page 176). This movement, determined by the grid configuration itself, is termed by Hillier et al (1993) *natural movement*.

However, the definition of natural movement makes it difficult to validate space syntax predictions: the urban grid is very rarely loaded in a uniform way. Consequently, measured movement patterns will always be biased. Building heights change from one location to another, thus modifying movement (taller buildings acting as generators of movement). A similar effect is produced by bus stops, underground stations, and by the type of streets, such as their width,⁽²⁾ the ratio of sidewalks to vehicle lanes, etc. In the axial map a pedestrian pavement and an urban highway would be counted almost the same.

It is true that the above would not constitute a problem if we assumed, like Hillier et al (1993), that urban attractors are a mere consequence of configuration: for instance, that the tallest buildings appear in the most integrated parts of town. In that case, attractors would simply reinforce natural movement, acting as multipliers. “In urban systems configuration is the primary generator of pedestrian movement patterns, and, in general, attractors are either equalisable or work as multipliers on the basic pattern established by configuration” (Hillier et al, 1993, page 31). (This multiplying effect is subsequently quantified in a logarithmic form.)

⁽²⁾The width of streets is partially taken into account in the process of tracing lines of sight to create the axial map.

Although this explanation can be seductive in the case of unregulated and organically growing urban systems, where attractors can influence urban growth undisturbed, it seems more arbitrary in the case of planned cities. Planning, as a deliberate decisionmaking process, might contrast configuration for the sake of many reasons, social, economic, and technical.

The Paris district of La Defense could be considered an example of this; it is a recently built office enclave composed of tall office buildings gathered around a wide pedestrian core. It was created by a political decision, namely the wish to collect tall buildings together outside the historic centre of the French capital. Despite being very poorly connected to the outside world and the adjacent urban areas, La Defense has a much higher pedestrian movement than its neighbouring streets (pedestrians originate mostly from underground car parks and the Metro/RER stations). This anomaly does not correspond to the integration values of the urban network and could not be detected by the analysis of an axial map.

3.3 The axial map and land use

Another limitation of the axial map is that it does not take into account land use. This is stated by Batty et al (1998, page 3): “[Space syntax] accessibility measures, although providing indices associated with forecasting trip volumes, are not based on models which simulate processes of movement and thus do not provide methods for predicting the impact of locational changes on patterns of pedestrian flow. In short although these indices can show changes in flow due to changes in geometry and location of entire streets, they are unable to account for comprehensive movement patterns which link facilities at different locations to one another.” (Batty et al subsequently argue for the use of agent-based models to simulate pedestrian movement.)

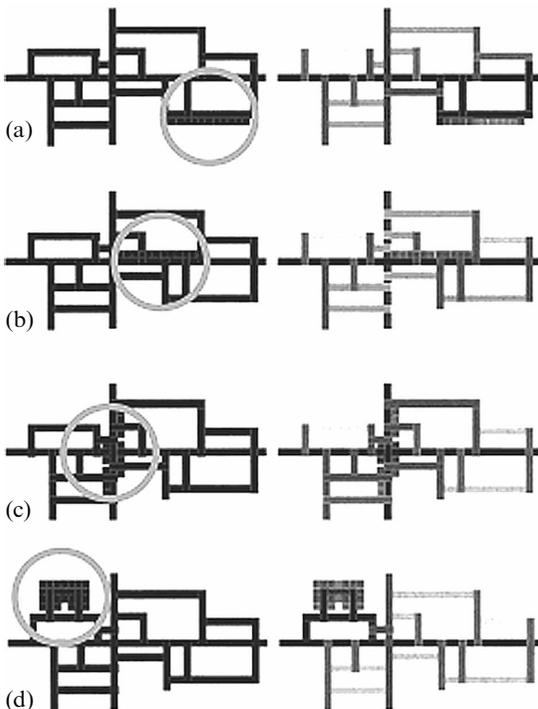


Figure 4. Notional street grid loaded with retail in different locations (source: Hillier, 1999). The effect of retail can be simulated by adding a certain number of nodes to the axial map—fictitious streets which have the effect of modifying integration values.

However, Hillier suggests a procedure to take into account land use, based on “adding land parcels representing, say, retail units as spatial elements in the appropriate locations [figure 4]. As these will not normally allow through movement, we are in effect adding new, more or less accessible destinations in certain parts of the grid. The effects, as shown in [figure 4], will be to weight locations according to the number of elements added and to increase the integration value of these locations” (Hillier, 1999, page 177). In other terms, fictitious streets (axial map nodes) are added where retail is and this changes the centre of gravity of the street network.

The procedure, however, seems quite ambiguous, as it arbitrarily assimilates an indoor commercial centre to a real street network. Furthermore, it does not provide any method to quantify these fictitious additions to the urban grid, leaving the possibility of unconscious postrationalisation—whereby it is the axial map analysis that mirrors movement and not vice versa.

3.4 Driving the axial map

Some uncertainty also appears in the process of producing the axial map from a piece of real urban texture. This process is based on selecting the ‘longest and fewest’ lines in the street network. However, several authors (Batty, 2001; Jiang and Claramunt, 2002) remind us that this is an arbitrary process, as there is no formal proof that a unique set of axial lines can be found. This uncertainty would change the topology of the axial map and therefore cascade onto space syntax results.

The above points 3.1 to 3.4 review some strands of an open debate on space syntax, and have been partly recognised by some authors—including Hillier—in their publications (see above). Two additional considerations appear below. They are based on the analysis of simplified urban networks and do not appear to have been formulated in this form yet.

3.5 The discontinuous nature of axial map transformations

This phenomenon is best described with an example. Take the two axial maps presented in figure 5. The first one, called (a), represents a city made up of regularly aligned blocks, such as the Roman castrum, post-Cerda Barcelona, or most uniformly gridded North American settlements. The second one, called (b), does not have a direct correspondence to real cities: it is a fictitious mesh obtained from the previous one by breaking it and slightly rotating each street segment, so that no two segments line up.

Imagine applying the axial map analysis to the two configurations. In case (a) all lines in the grid would have the same integration value, as each of them intersects exactly 6 streets of depth 1, which in turn intersect 5 streets of depth 2. In contrast, in case (b), segments near the core of the system would be more integrated than peripheral ones: all segments being the same length, the topological distance is proportional to the geometric one, therefore producing a centripetal integration pattern.

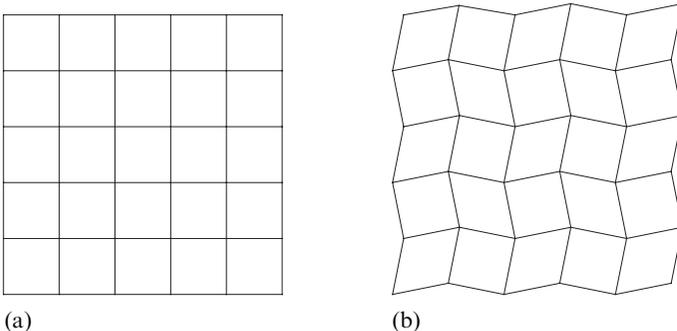


Figure 5. An orthogonal axial map (a), and a ‘broken’ or deformed one (b).

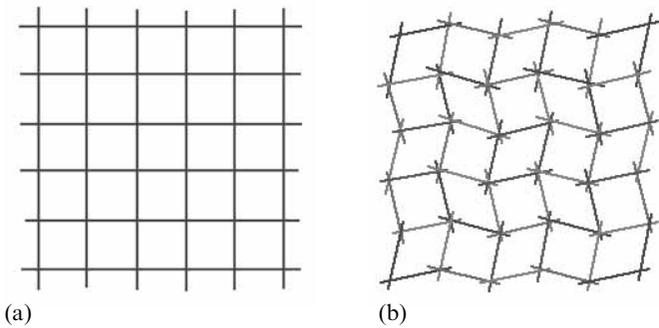


Figure 6. Global integration values on the two axial maps of figure 5; they were calculated using the software Axman PPC release 2.5, courtesy of the Space Syntax Laboratory, University College London. Map (a) presents a uniform integration value 3.134, whereas map (b) varies between 0.919 (corner lines) to 1.930 (central lines).

The space syntax software Axman PPC release 2.5, from the Space Syntax Laboratory at University College London, proves this fact, as shown in figure 6. A main difference between the two configurations is the pattern of integration, uniform versus centripetal. Furthermore, important changes appear in numerical values, with (a) scoring a uniform 3.134 and (b) any value between 0.919 (central segments) and 1.930 (peripheral segments). According to space syntax very different patterns of movement would be predicted in the two cases, with pedestrians crowding the central part of (b) or uniformly distributed in (a). Note some similarities between the discussion developed here and the so-called ‘visibility paradox’ (Hillier, 1996, page 341, figure 7). However, Hillier uses the visibility paradox to point at conflicting forces that govern the growth of cities, without exploring the implications for space syntax analysis.

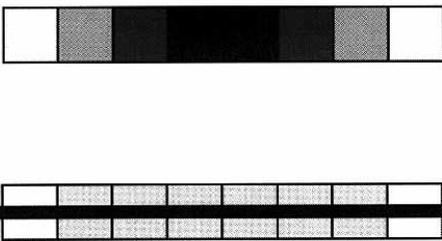


Figure 7. The visibility paradox. A number of separate cells arranged in a line will produce a central integration pattern (highest integration in the middle); however, if a single line of sight is superimposed and used for the axial analysis, a uniform pattern is obtained (source: Hillier, 1996).

It is surprising that such similar configurations produce such different results. Furthermore, consider now how the two axial maps could be obtained from real urban textures. According to the space syntax definition, the axial map is obtained by selecting the ‘longest and fewest’ lines of sight that can be traced in the street network. Configuration (a) would appear in any city with orthogonal straight streets; configuration (b) would be obtained in a fictitious city such as the one presented in figure 8 (see over). Although in general it has been seen that the procedure to draw the axial map is not unique, this is not the case here because of the simplified geometry.

Imagine deforming grid (b) progressively by reducing its skew, so that it slowly approaches (a). Initially, the corresponding axial map would remain unchanged, that is, ‘broken’. Then, abruptly, at a certain critical angle (figure 9, over), lines of sight will ‘pass through’ from one street to the next and grid (a) will be obtained. At that critical angle,

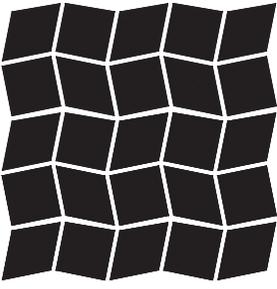


Figure 8. Example of urban texture (buildings are shown in black) which would produce the deformed axial map of figure 5.

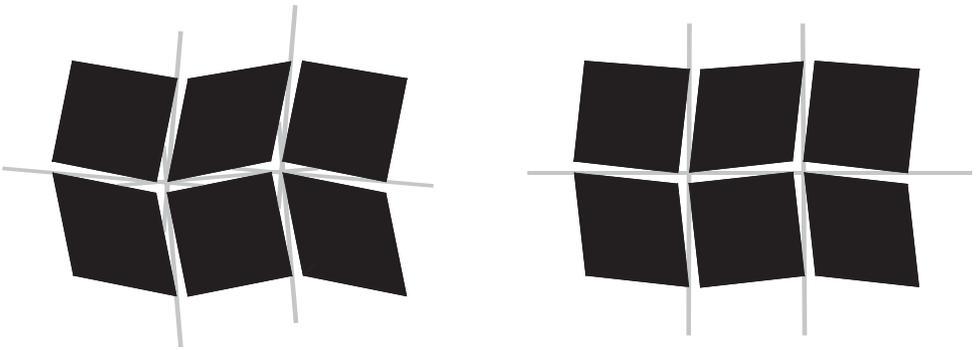


Figure 9. A small deformation of the urban grid of figure 8 would produce a short-circuiting effect—an abrupt change in its axial map, from configuration (a) to configuration (b) in figure 6. On the left image the intersection of the four lines of sight does not happen exactly in one point, but in two adjacent ones: because of their proximity, however, they count as one in space syntax analysis.

a curious phenomenon appears: the same geometrical arrangement, if approached from one side or the other, produces two different axial maps (corresponding to radically different integration patterns). Put mathematically, it is a discontinuity in the transformation from geometry to topology, a singular point where two different outputs correspond to the same input.

The above example, beyond its curiosity, is important because it shows a more general phenomenon: the binary nature of topological transformations. If a certain city undergoes a progressive and continuous change of geometry, its topological representation varies in a discontinuous way. A finite or quantum change happens each time two axial lines collide and short-circuit. The process is extremely evident in the above example because of synchronisation and simultaneity, but it is present in any geometry–topology transformation.

This short-circuiting effect does not undermine space syntax theory in itself—which remains an interesting method to characterise urban configuration with some tools of graph theory. However, it poses a number of problems as far as the correlation of integration values with movement and the social logic of space is concerned. Can it be accepted that human behaviour as a function of urban configuration changes in quantum leaps or that pedestrians would respond in significantly different ways to virtually the same geometry?

3.6 Axial map edge-effect

The edge-effect phenomenon is best explained by an example. Take the axial maps of two separate urban systems. For the sake of simplicity let us choose configuration (b) above, whose space syntax results are already known: maximum integration and therefore movement in the central portion of the network (figure 10).

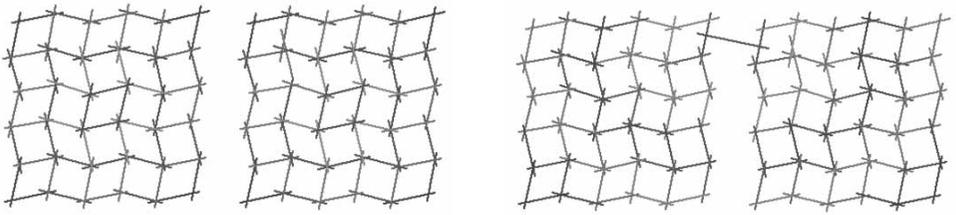


Figure 10. Global integration in two urban systems, first considered as separate entities and then put into communication. Values calculated using the software Axman PPC release 2.5, courtesy of the Space Syntax Laboratory, University College London.

Now imagine putting the two systems into communication with each other: the integration patterns would be altered, as shown in figure 10, and the most integrated part would become the line connecting the two systems (and adjacent segments).⁽³⁾

This fact is known in space syntax theory. It can be considered a corollary of Hillier's (1996, page 340) 'paradox of centrality', which states: "maximising internal integration also maximises external segregation". When a self-contained urban system is put into communication with the outside world, its central part, which was until then the most integrated one, becomes rather segregated.

The full consequences of this 'paradox', however, do not seem to have been explored. Let us focus on the left axial map: the change in integration produced by connecting it with the right one can be interpreted as sensitivity to the boundary conditions. Results of the space syntax analysis are influenced by the extent of the city that is being considered. An edge-effect appears, which has pervasive consequences over the whole urban network and affects results even in remote locations.

Unfortunately, the problem of sensitivity to boundary conditions does not seem to have found a satisfactory answer in space syntax. Dalton (1997), based on Hillier (1996), suggests using local integration (say integration of radius 3, or so) instead of global integration, in order to reduce the edge effects.⁽⁴⁾ However, the work of Hillier et al (1993), which is the fundamental reference on correlating the axial map results with movement, uses global integration. Selected urban portions (such as the King's Cross area in London) are analysed, without clearly explaining how their boundaries have been selected. What extent of the adjacent urban portion should be included in the axial analysis? This question does not have a clear and uncontroversial answer.

4 Discussion and conclusions

This paper reports on a number of inconsistencies that appear in space syntax, a well-known technique to investigate the urban environment. A number of case studies are examined, based on simplified geometrical arrangements, where some conflicts occur.

Although some of these arguments have partly been recognised by other authors before (including Hillier), they were never presented in a comprehensive form. Also, points discussed in 3.5 and 3.6 do not appear to have been mentioned before: namely, the discontinuous nature of axial map transformations (3.5) and the axial map edge-effect (3.6). Both of them exemplify some kind of short-circuit effect that appears when dealing with topological representations of the city, under certain geometrical conditions.

⁽³⁾ Something similar to the process of abruptly joining two separate urban systems might have happened in New York in 1883, with the opening of the first permanent connection between Manhattan and Long Island (the Brooklyn Bridge). It would be interesting to investigate what the effects were on pedestrian and vehicular movement.

⁽⁴⁾ A more precise option could be weighting the axial lines during the integration process with a decay function.

Much of the criticism reviewed above derives from the fact that the information contained in the axial map (the only input to space syntax) has been reduced. The use of a topological support and the rejection of valuable information about cities (such as metric) pose some major practical and conceptual problems.

Although a simplified format and a concise representation of the street network would probably have been a necessity in the early days of space syntax, when computing resources were scarce, it is possible today that a more complete analysis based on a richer support would be helpful to understand the ‘social logic of space’. The success in the use of the axial map “is not to say that a more refined form of analysis... would not yield even better results” (Hillier et al, 1993, page 35).

New computer techniques are being developed at a fast pace to allow a deep exploration of urban texture. I have used raster digital elevation models (DEMs) in urban areas to derive a number of useful parameters, such as visibility, travelling time, and accumulated distance (Ratti, 2002). This allows a quick exploration of the metric—as well as topological—properties of space. A similar approach is proposed by de Smith (2004), who discusses the role of distance transformations in exploring the urban environment. New insights on the social logic of space are also likely to open up with the forthcoming introduction of a new generation of smarter agent-based models. All of these computer techniques, coupled with the increasing availability of urban datasets, might throw a deeper insight into one of the fascinating questions that traditional space syntax has helped framing: what is the influence of urban configuration on social life?

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