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The syntactical image of the city:

A reciprocal definition of spatial elements and spatial syntaxes

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Abstract

This paper presents a study of the relationship between city elements, as defined by Lynch, and the spatial descriptors commonly used in space syntax research, leading to a proposed relationship between the hitherto unrelated concepts of intelligibility and imageability. The paper starts by demonstrating how each of Lynch's five city elements (the node, path, district, edge and landmark) may be redefined using a selection of spatial notations, primarily the axial line and the isovist. Furthermore, by precisely defining the relationship between the axial line and the isovist, it can be shown that all of Lynch's elements may be redefined using a single, coherent family of tightly-related spatial entities. A case study of Boston, circa 1950, is used to test an application of these redefinitions and the relationships between the various spatial descriptors and Lynch's elements. In turn, this leads to a hypothesis concerning the relationship between the concepts of intelligibility and imageability, concepts that were previously considered to be independent. Finally, the paper concludes by building upon the relationship between intelligibility and imageability to conclude that this relationship provides strong evidence for an underlying cognitive basis to space syntax.

Keywords

intelligibility,
imageability,
legibility, city design,
"Boston", edges in
wayfinding,
landmarks,
district, nodes, paths

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1. Introduction

Kevin Lynch, in *The Image of the City* (Lynch, 1960) argued for *legibility* being a significant quality of the city. According to him, the legibility of the city, or "the ease with which [a city's] parts can be recognised and can be organised into a coherent pattern", is significant not only for aiding practical tasks such as way-finding, but also that it is central to the emotional and physical well-being of the inhabitant population, personally as well as socially. He continues by equating the legible environment with an "imageable" one. Imageability, according to him, is "that quality in a physical object which gives it a high probability of evoking a strong image in any given observer. ... It might also be called *legibility*."

Space syntax researchers have also sought to capture the quality of an environment as being comprehensible and easily navigable, which they recognise as its 'intelligibility'. The definition of an intelligible environment is given in the

book *Space is the Machine* (Hillier, 1996) where it says that “The property of ‘intelligibility’... means the degree to which what we can see from the spaces that make up the system - that is how many other spaces are connected to - is a good guide to what we cannot see, that is the integration of each space into the system as a whole. An intelligible system is one in which well connected spaces also tend to be well-integrated spaces. An unintelligible system is one where well-connected spaces are not well integrated, so that what we can see of their connections misleads us about the status of that space in the system as a whole.” The definition of intelligibility concerns the relationship between local visual cues (e.g. the connectivity of a space) and the global properties of a space within a system. In an intelligible world (where the relationship between local and global properties of space is strong), this relationship assists subjects in efficient navigation. In unintelligible worlds, this approach fails to assist them, as the relationship between the local and the global is less strong, even misleading; in these worlds, they become lost.

There seems to be a fundamental and, perhaps, irreconcilable difference between these two approaches—one focussed on visual qualities of the city, and a method that tries to elicit the inhabitants’ mental maps of their city, the other focusing on abstract spatial descriptions and a method which seeks to reveal their underlying structure or structures in relationship to observable behaviour. Our purpose is to examine to what extent the two approaches can be mutually reconciled. We will do this by investigating the correspondence between Lynch’s cognitive mappings of cities in terms of five elements—nodes, edges, districts, landmarks, and edges—and a syntactic mapping of the city.

2. First and second order elements

An obvious starting point is to attempt to re-interpret Lynch’s five environmental features in terms of the basic spatial descriptors commonly used in space syntax research. The motivation behind reinterpreting Lynchian elements in space syntax terms is not reductive—we are not claiming that all of the Lynchian elements can be completely characterised in terms of syntactical variables—but rather the effort is to find out how much of Lynch’s theoretical approach and his specific findings can be accounted for by a syntactic approach. Our study, therefore, has a two-pronged approach. On the one hand, we will try to determine whether there is a syntactic logic underlying the basic descriptive elements through which Lynch describes the inhabitants’ cognitive maps of cities, and on the other, we will try to offer a syntactical argument for why particular environment-features of the selected study area are picked up by Lynch’s subjects and not others.

Our argument is that Lynch treats his five elements in a resolutely empirical sense; he seems to have identified them as being the best elements available for characterising how inhabitants map their cities, without making a case for how they come together to give a systematic mapping of cities. Despite his reticence on the subject, however, it is easy to see that the elements are anything but random. We can sort these elements into two groups. At the first level are the *spatial* descriptors—nodes, paths, and districts. They are elements of zero, one, and two dimensions that observers acquire and utilise as anchors for location, and the relationship of these elements to the observer is topological. Not only can the observer position himself in space in terms of basic topological relationships (“to the front of”, or “to the right of”) but also ‘at’, ‘on’, or ‘inside’ them. At the next level are primarily *visual* descriptors—edges and landmarks. The observer’s relationship to them is of a higher geometrical order (at least projective), in that he/she locates her position vis-à-vis these using a rough polar or vector orientation (a sense of both distance and direction), but does not actually occupy them.

This distinction seems to be well borne out by recent studies in wayfinding. Benjamin Kuipers and his fellow researchers, for instance, have argued that wayfinding subjects routinely plan their routes using a mental map constructed in terms of a skeleton¹ of paths, against which both areas and specific locations can be identified and discussed (Kuipers, Tecuci and Stankiewicz, 2003). Findings such as these seem to suggest a *hierarchical* difference between the spatial and visual elements. The mental map is essentially structured by the spatial elements, which then may be elaborated, or fine-tuned by the addition of visual elements. We therefore refer to the spatial elements as “first order elements”, and the visual ones as “second order elements.” The sense of structured coherence that the spatial elements provide seems to play a more crucial role than the sense of visual distinction or imageability that is central to Lynch’s thinking.

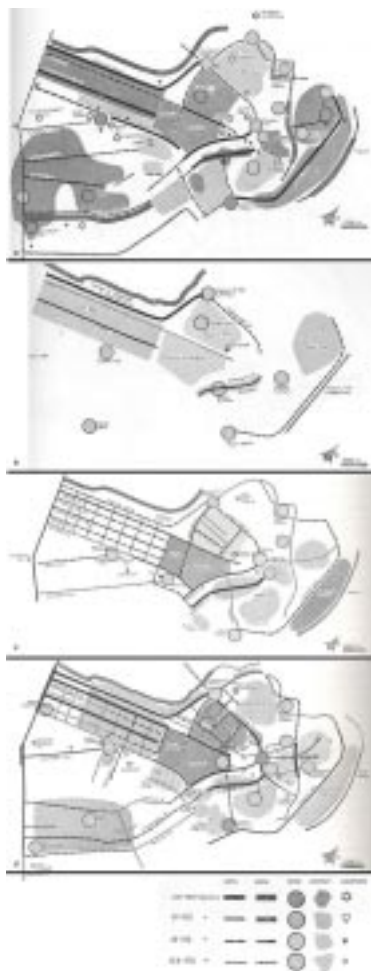
It is interesting to note that not only is Lynch clearly aware of the significance of the sense of coherence, methodologically his approach is directly premised on it. His intentions are 1) to arrive at a sense of dependable accuracy in his studies, and 2) to be able to generalise his method so that an appropriate city image can be constructed by a procedure that is both standardised and accurate and can only be realised if the inhabitants’ cognitive map of the city is not merely a collection of features in terms of the five elements, but a *systematic structure* constituted by them.

One point where we suggest that space syntax contributes to a Lynchian study is by providing just this systematic description of the city. Its most pertinent contribution is to offer a sense of relative hierarchy to the different constituent

elements of the city. Where Lynch's elements are overtly differentiated (or formally unlike each other), space syntax describes the city in terms of elements that are, in themselves (i.e. formally), undifferentiated, but gain differentiation through their relative position within their overall spatial configuration. Such a description is able, therefore, to filter out all their effects on the intelligibility of the city, except for those due to spatial configuration.

We intend, then, to discuss how each of the Lynchian elements may relate to a syntactical mapping of the city. Intuitively, the first order elements seem to lend themselves to easy description; paths may be described in terms of axial lines, nodes as their intersections, and districts as groups of intersecting paths with distinctive properties. But the more significant question to be answered is which subset of all possible axial lines, their intersections, and their groupings find their way into the mental map of inhabitants as nodes, paths and districts. Space syntax has typically defined urban configurations in their totality; whereas Lynch's study demonstrates that inhabitants' mental maps of the city are *selective* and depend as much upon certain features of the city being excluded as much as upon the features of the city that are used to characterise it. Lynch, however, does not offer any arguments for why some elements are selected over others, claiming instead that their distinctively visual characteristics are responsible.

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Our second intention is to demonstrate, against this Lynchian claim, that it is not fundamentally the visual qualities of the elements, but their structural qualities that may lead to their being selected, and that space syntax offers a way to characterise those. Interestingly, Lynch himself provides us a way into this. Lynch's study was intended to develop a general method for mapping the city in terms of its most significant or imageable elements. In order to test the efficacy of his method, he sought to compare three different maps of the city with one that trained observers had prepared (Figure 1a). These three maps included one that was based on elements that the subjects picked out from a set of photographs (Figure 1b), another that was compiled by putting together sketch maps that subjects constructed in response to particular queries (Figure 1c), and a third that was constructed through verbal interviews (Figure 1d). Lynch points out that these three provided results of an increasing degree of selectivity, with the verbal map being the least selective (or having the most number of elements), and the map of photographed elements having the fewest number of elements.

Figure 1: Map of Boston showing visually distinctive elements (source: Lynch, 1960)

We argue that the difference of selectivity indicates very clearly the role of overall context in the imageability of the city—that inhabitants recall elements, not primarily because they are visually distinctive as such, but only within the context of a particular route or situation. The first two maps were clearly constructed from situations in which the inhabitants recalled elements in particular contexts. Syntactical representations should therefore account for all those elements that feature in verbal and sketch maps, but not in the map constructed from photographed selections.

Another important point to note is the difference between the verbal and the sketch maps. The sketch map, Lynch finds, is more selective than the one verbal one; however, some elements that occur on the sketch map are not found on the verbal one. This can only happen if those elements are not intrinsically visually distinctive, but are crucial within an overall *wayfinding structure*. In this paper we attempt to see if syntactical descriptions can account for these.

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3. Axial lines and isovists

The question that naturally arises, at this point, is *which* syntactical descriptions will best help our case. The axial line representation seems the ideal descriptor, partly because it is the commonest representation in the space syntax repertoire and empirically the most successful for urban contexts, and partly because it is the closest to computational studies of wayfinding (Kuipers, 1996; Kuipers, Tecuci and Stankiewicz, 2003; Penn, 2003). However, Lynch's stress on the visual characteristics of elements does raise the question of whether we should be including other spatial representations in this paper, and the isovist appears a potentially useful candidate.

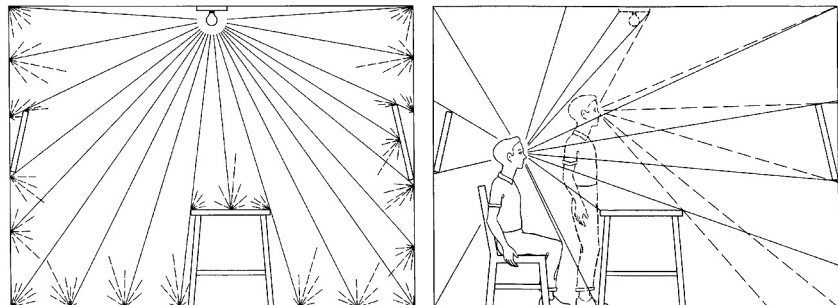
What we would like to clarify, in this context, is recent work, which can be held to bridge the conceptual gap between the concept of the axial line and the isovist². The traditional definition of the axial line is that it represents the fewest and longest lines of sight that pass through every space comprising any system. The definition of an isovist is that it is the field of view, available from a specific vantage point; a horizontal slice through this field of view is then calculated, usually taken at eye height and parallel to the ground plane. It is the resulting polygonal representation of this two-dimensional, visual 'slice' that is referred to as an isovist. It is worth noting that axial lines and isovists are one and two-dimensional representations respectively. (Viewsheds, used predominantly by geographers, are on the whole, three-dimensional and represent the entire field of view from a single location).

The importance of establishing the computational or geometric connections between isovists and axial lines and other spatial representations will be expanded upon in this paper. Essentially, however, isovists can be seen as acting as the primary, intermediate spatial representation, connecting Lynch's definitions of his five key elements to space syntax definitions.

To begin to construct the relationship between these various spatial representations, imagine a sort of "primal soup" of all possible lines of sight present in an environment. There are obviously an infinite number of these lines. This 'primal soup' of lines would comprise all possible lines of sight that pass through every possible point in an environment and are positioned at every possible orientation. We would suggest that this could be held to be analogous to (but not identical to) Gibson's concept of the ambient optic array (The structure inherent in the light producing a retinal image, which provides information concerning spaces, surfaces, and textures/materials for a situated observer (Gibson, 1966)). In essence, an observer in an environment will occupy a place at the convergence of a near-infinite number of rays of scattered/reflected light. These 'angles of intercept' change as the observer moves, thus enabling us to perceive the environment around us. See Figure 2.

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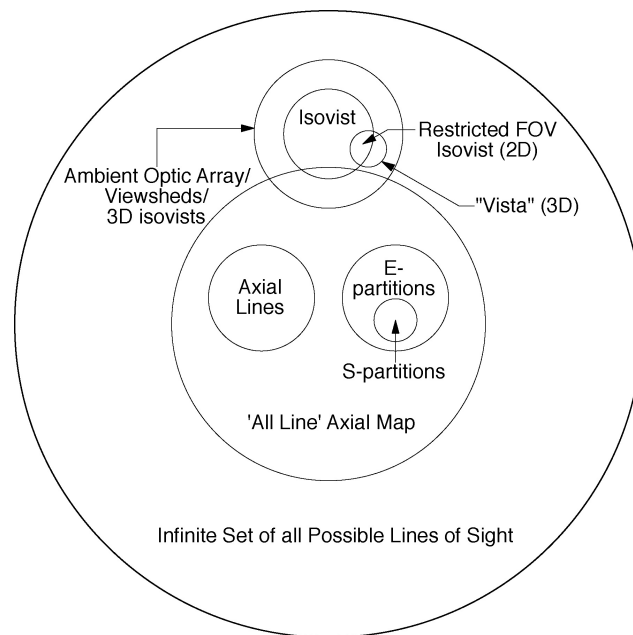
Figure 2: Gibson's Ambient Optic Array (source: Gibson, 1966)



If we consider Gibson's Ambient Optic Array to be the aggregation of the near-infinite number of lines of sight that happen to pass through a single point in space, it could be said that this is directly equivalent to the concept of the viewshed or what might be termed a 3D isovist. Equally, if we imagine a 2D slice through this rich visual field, this is an isovist, as defined by Benedikt (Benedikt, 1979). Our redefinition of the isovist, for the purposes of this paper, *is that an isovist is the sum of the infinite number of lines of sight (or axial lines) that pass through a single point in space (usually at eye height³) and occupy the same plane (usually parallel to the ground plane).*

In summary, it can be seen that Gibson's ambient optic arrays, viewsheds and 3D isovists are all sub-sets of the universal set of all possible lines of sight present in an environment. Equally, the isovist can be held to be a sub-group of the

ambient optic array (or 3D isovist, viewshed). A sub-set of the isovist is the 'restricted field of view isovist' (e.g. where the FOV is, for example, equivalent to normal human vision, approximately 180°). Finally, the term *vista* as used commonly in architectural writings is usually meant to be three-dimensional and therefore the vista could be held to be a subset of the viewshed (and not the isovist). See Figure 3 below for a diagram of the relationships between these different representations of groups of sightlines.



59.7

Figure 3: The Relationship between Isovists, Lines of Sight, and Axial Lines

Let us next consider the spatial representation known as the 'all line axial map'. This is not *literally* all the lines of sight that pass through an environment, as this would be infinite in number (indeed, this would be the *universal set* as out forward in this taxonomy). Instead, the all line axial map, consists only of the most *strategic* of these lines: the lines that connect any pair of mutually visible edges plus the extensions (if any) of these lines (until termination at a surface or boundary). Axial lines (The fewest and longest lines of sight that pass through every space in the system) form a small sub-set of the 'all line map'. Although it has never been attempted computationally, it has been suggested by a number of different ⁴ researchers that the relationship between the 'all line map' and the 'axial map' can be established through a process known as clique concatenation. A group of lines, all of which are connected to the same set of lines, can be regarded as a clique (everything connected to everything else). Clique concatenation, in a graph, is the replacement of a clique, by a single node, or this case a single line. That line could either be selected randomly from the clique, selected on the basis of its attributes (the longest line would be an obvious choice) or even a geometric mean of the lines forming the clique ⁵. It is postulated by the authors and other researchers that were the process of clique concatenation to be performed on the 'all line map', the resultant representation would be the axial map.

If we consider *briefly* isovist integration or VGA analysis, there is a relationship between isovists and convex shapes. If an isovist is generated from an array of vantage points forming a regular grid filling all possible navigable space, then the relationship of isovist connectivity (or mutual visibility between points) can be established. In work by Turner et al they established that each clique in the graph is analogous to a convex space. That is to say, a space inside of which any pair of points are mutually visible.

A formalisation that used the single concept of the line of sight to create both a consistent convex partitioning and a definite axial line structure for any spatial setting has been suggested by Peponis and his colleagues (Peponis, Wineman et al., 1997; Peponis, Wineman et al., 1998). Using only the *extension* part of the lines of the all-line map as boundaries, Peponis and all show how a given space can be partitioned into informationally stable shapes called E-spaces (or using a more limited set of all line extensions, into S-spaces), and these in turn used to automatically generate axial lines.

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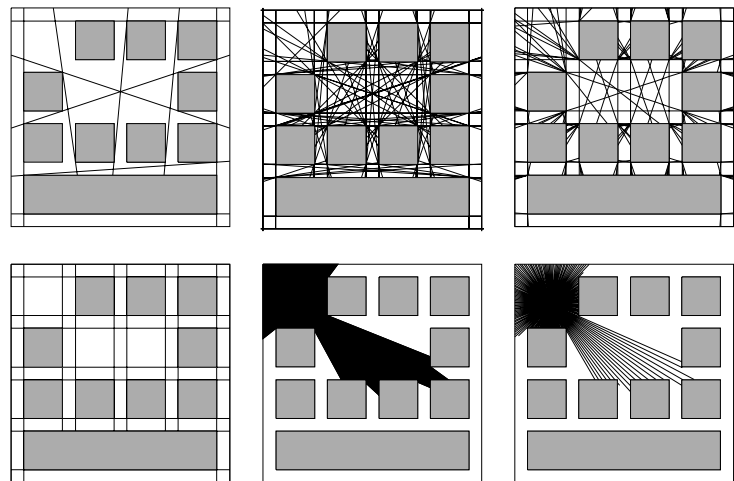


Figure 4:(from left to right, top to bottom; Axial break-up, All line map, E-partitions, S-partitions, Isovist and the Isovist as a Set of Radiating Sightlines

This brings us back full circle (Figure 4), as the original definition of the axial line was the fewest and longest lines of sight such that they pass through every (convex) space in a system⁶. These recent studies, therefore, all show how much the visual characteristics of a spatial configuration are already embedded in its axial map. The difference between the axial line map, and an isovist is not so much that one is spatial and other visual as sometimes hastily summarised, but that one allows mapping of a local to global structure but at a serious attenuation of local characteristics, while the other preserves much more of a local spatial information, but does not allow a natural global extension of it. Given that our emphasis is on capturing the structural element of the city image that Lynch misses, our main tool will remain the axial line; for some specific categories, particularly the node and landmarks, the isovist will feature more strongly.

4. Syntactical interpretation of the Lynchian elements

To reiterate, we intend to show that there is an underlying spatial logic (and structural, not merely visual) that determines both, the categories of elements that Lynch uses, as well as the specific features of cities that the inhabitants select as being key to their image of the city, and therefore that syntactic descriptions are a very useful way of capturing this logic. Given the empirical basis of our claim, our following argument is presented in the context of a specific example. We present an analysis of Boston c. 1950s (Figure 5), which is one of Lynch's case studies, and compare it with Lynch's maps (Figure 1).

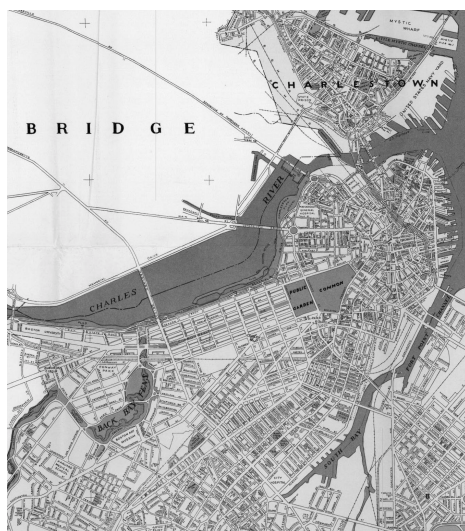


Figure 5: Boston, c. 1956

(source: Mapjunction, Agog Inc. Grand Ledge MI, www.mapjunction.com)

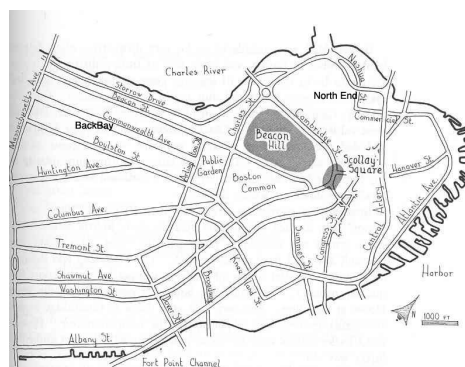


Figure 6: Major roads and districts in downtown Boston (after Lynch)

4.1 General comment on the axial mapping⁷

The axial map (Figure 7; unrestricted radius) picks out the significant roads in Boston with remarkable clarity, available even to a simple visual inspection (see Figure 6 for identification of major roads and districts). The axial line of Beacon Street is the most highly integrated, which is quite understandable given its length and high connectivity with lines representing other key roads, and similarly for Charles Street, Huntington Avenue, Massachusetts Avenue, and Columbus Avenue. More interesting is the sharp emergence of streets with smaller lengths or relatively lower connectivity values, but which are important features in the inhabitants' visual map of Boston—

Washington Street, Tremont Street, and Cambridge Street. Visually identifiable features such as the general high degree of integration in the Backbay region, and the sudden drop in integration values in North End (cut off by the Central Artery) also contribute to the sense that the axial map captures the cognitive image of Boston very well at a general level.

Figure 7: Axial map of Boston (unrestricted radius); darker lines indicate higher integration



59.10

5. First order elements

The first order elements seem to call for interpretation essentially through an axial map, but given the fact that we have described these elements as the inhabitable ones (those which may be occupied), it is also possible that characteristics of *isovists* from these spaces would also contribute to their distinction. This point is particularly true of nodes, as will be discussed below.

5.1 Paths

Lynch describes paths as channels for potential movement, “Paths are the channels along which the observer customarily, occasionally, or potentially moves. They may be streets, walkways, transit lines, canals, railroads.” (1960: 47). He makes the connection between the visual experience of the city and paths because the greater part of our city experience arises from our movement through it. At the most basic level, Lynch’s paths can be seen to be analogous to axial lines in space syntax terms. An axial line also combines the dual notion of movement and vision, representing both a strategic line of sight and often potential for movement.

The obvious thing to suppose is that lines of high integration will coincide with the significant paths in Lynch’s maps. This seems to be more or less the case. Of the different mappings developed by Lynch, the axial map is much closer to the map derived from sketches than from the one derived from verbal interviews. As Penn et al have suggested, such a correspondence may be more characteristic of highly intelligible areas (Penn, 2003). However, there are some noticeable discrepancies.

Commonwealth Avenue is the most significant path in Lynch's study, but its position is much weaker in the axial map (unrestricted radius). This alerts us to the fact that some paths are significant not so much due to their connections, but primarily due to their visual character. Commonwealth Avenue is a very broad tree-lined avenue, split into two separate lanes separated by a strip of park. Storrow Drive loses its significance due to its lack of connections; it is a stretch of freeway that was built to connect the interstate highway system of the Central Artery directly with the eastern side of Boston, and bypasses most intermediate roads. This means that although it has a distinct visual character (primarily derived from its location along the Charles river), it is not so significant within the internal movement economy of Central Boston. This observation is well illustrated by the comparatively lower significance of both these paths in the sketch maps of the Lynch study as compared to the verbal map. The drop is sharp in the case of Storrow Drive—from a frequency range of over 75% to one between 25-50%, but less pronounced in the case of Commonwealth Avenue⁸.

59.11

These discrepancies point to another issue that the axial map may help clarify: the difference between the interview map and the sketch map images from the Lynch study. Lynch (1960, 144) observes 1) that although the sketch maps and interview maps for particular individuals did not show a high degree of correspondence, the composite sketch maps did correspond well with the composite map constructed on the basis of verbal interviews, 2) that the sketch map had a higher threshold of registration of elements, i.e., a tendency to be comparatively sparse, and 3) that this tendency was more pronounced in the case of Jersey City, which, as Lynch points out, was comparatively poorly differentiated. We can identify further differences: 1) as compared to the interview map, the sketch map is far less differentiated in terms of the relative frequencies of the paths picked out, and 2) the sketch map dissolves differences between segments of streets. In Boston, Beacon, Charles, and downtown Washington streets, all of which have segments with different degrees of significance in the verbal map, emerge as undifferentiated continuous segments in the sketch maps; the only notable exception in this sense is Boylston Street.

The axial map helps account for these differences. First, it helps downplay the particular strength that elements with strong visual characteristics acquire in the interview. The few paths that are picked-up strongly in Lynch's map of the distinctive elements of Boston—Storrow Drive, Commonwealth Avenue, Atlantic Avenue, and Cambridge Drive—are the very paths that mark the difference between the sketch maps and the interview maps. And these are precisely those significant paths of the interview map that the axial analysis fails to pick up. Second, it allows the capturing of the structural sense of the city, an aspect that Lynch is aware of, but is unable to

assimilate to the dominant visual bias of his study. The sketch map, which is arguably the map that comes closest to mapping of city in use, rather than as conceptualised, is therefore easily explained by the axial structure.

The distinction between paths and axial lines might be seen to diverge from the perspective of linearity. Lynch's paths certainly contain no constraints in terms of angle, namely that one path can be quite 'meandering', whereas such a path would need to be represented by any number of axial lines. This difference can be addressed either by considering fractional integration (Dalton, 2001) or by comparing the Lynchian path to a set of axial lines at the level of the graph - namely that a path is equivalent to a sequence of axial lines providing a contiguous route from an origin, A, to a destination, B, through the graph.

59.12

5.2 Nodes

The presence of nodes is more of a puzzle than that of paths—there seems to be no reasonable method to account for where they occur, particularly with respect to the axial map. Lynch (1960, 72) distinguishes two types of nodes—those that are at major intersections, and those that are characterised by concentration with a thematic activity. Lynch's distinction between the two types of nodes is actually not so informative; it does not help understand the characteristic features of nodes. Considering his description of the actual nodes in the three cities, there seem to be two senses in which he finds the nodes important to the imageable visual character of the city.

On the one hand, nodes are key points used in wayfinding tasks, or points at which crucial route choices are offered to the subject. This type of node does not need to have any distinctive physical or visual characteristic. Clearly, such a node would be able to be identified through axial analysis. Oddly, very few of the nodes that appear on Lynch's maps seem to lie on the intersections or even in the vicinity of strong axial lines. In fact, nodes like Louisburg Square in Boston are on highly segregated lines.

However, an interesting observation occurs if we compare the different maps produced for Boston in Lynch's study. As in the case of the paths, the verbal map produces the maximum number of nodes, followed by the sketch map, and then the map of recalled distinctive elements. As a rule, all the nodes in the latter two maps occur in the first one, with one major exception. The crossing of the Columbus, Boylston, and Charles streets at Park Square is not picked up in any of the maps except the sketch map. There it is a major node; in the axial map, that is one of the intersections where not only the most globally integrated streets meet, but also the

most locally integrated. This could imply that observers may not be visually aware of key decision points in their paths; they are more likely to show up in their behaviour. The sketch map would be one way to pick-up such nodes, but may not be sensitive enough to distinguish normal crossings from key ones. The axial map could therefore be an efficient way to highlight such nodes.

On the other hand, consider Lynch's characterisation of the Piazza San Marco as an exemplary node, a node characterised by a *strong visual character*. Lynch states that the nodes have the somewhat paradoxical quality of being both distinctive in comparison to their surroundings, and simultaneously intensifying some of their characteristics (1960, 77). This definition is not very precise as it reduces nodes to simply being memorable places within the urban fabric. His definition of Louisberg Square as a place which is visually memorable but not localisable even within its district (Beacon Hill) makes it fundamentally different from Piazza San Marco, in which the visitor may not only be oriented locally within the piazza, but also use that orientation to place himself with respect to the rest of the city. It is not clear from Lynch's discussion what a node like Louisberg Square would provide to a visitor in terms of either wayfinding or general orientation within the city. Once again, it is of interest to note that Louisberg Square features in both verbal and recalled elements maps, but not in the sketch maps of Boston.

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Lynch also states that Scollay Square in Boston lacks directional quality or a recognisable shape, and does not provide any sense of orientation. But it may be argued that Lynch is focusing somewhat excessively on well-defined shape as being visually memorable. Scollay Square might actually offer a very good sense of orientation, primarily because of its clearly convex form. In other words, Lynch's discussion of nodes does not differentiate between nodes that contribute to a sense of orientation and assist in way-finding, and nodes that may confuse or hinder it.

Our discussion suggests that isovist mappings of the nodes might help characterise further the significant nodes (or at least those which are potentially significant). Such nodes would need to have highly concave shapes (visually penetrating star-shapes rather than convex spaces), strong visual asymmetry, and proximity to highly integrated axial lines. There may be visually prominent places in city that lack these characteristics, but we believe that such places would not contribute to the sense of orientation of the city.

Equally, other properties such as isovist area to perimeter ratio, mean isovist length (Conroy 2001), circularity (Benedikt, 1979) or entropy (Turner et al., 2001) may come into play here. In Conroy's work she demonstrated the importance of

such locations in wayfinding behaviour, which suggests that these are locations where people stop and re-evaluate the environment, assessing wayfinding decisions already made against novel environmental information.

The testing of these ideas require maps of more detail and better accuracy than were available to us, but would be recommended for further work.

5.3 Districts

Districts, like nodes, lack overt identification with the axial map. Axial maps inherently do not provide any sense of a hierarchical structure in their mapping of the cities or buildings. The use of developing hierarchical structures in residential plans as a means to characterise their genotypes has been discussed in space syntax literature (Amorim, 2000; Bafna, 2000; Bafna, 1998), but the issue has not been little discussed with respect to urban structure. No techniques exist at the moment for capturing the natural emergence of distinct districts within a city, a phenomenon that Lynch (1960: 67) points out as being both ubiquitous and highly relevant to the image of the city; the inherent sense of 'district' makes Manhattan both highly memorable and appearing to be smaller than reality.

However, once districts are known, the axial map provides a useful means to understand their characteristics (see discussions of several housing estates, as well as Barnsbury district, in London in Hillier, 1996, and Hillier et al., 1993) for an illustrative case). Certainly, it has been established that we can judge the nature of a district by the distribution of syntactic values of its axial lines, and how it is embedded within the larger system of the city.

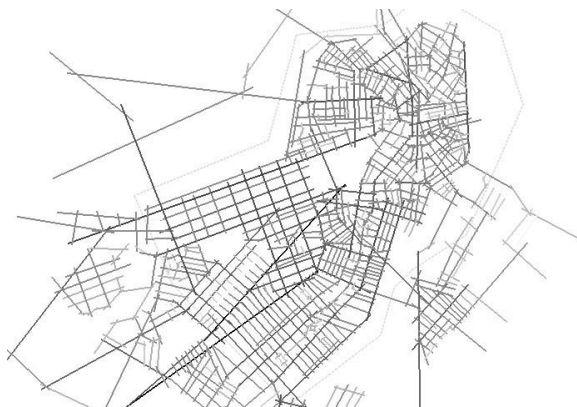


Figure 8: Axial map of Boston (radius 3); darker lines indicate higher integration

Consider Beacon Hill. Its few lines span much of the range of integration values of the entire system, and match its intelligibility (Integration at radius 3 versus Integration at unrestricted radius). The good correlation ($R^2 > 50\%$) between Integration at radius 3 and at unrestricted radius suggests that the local structure of

the district remains the same at a global scale as well; the internal configuration of the district works similarly at both local and global levels (Figure 8 and 9a). This illustrates the characteristics of a well-structured and highly orientating district.

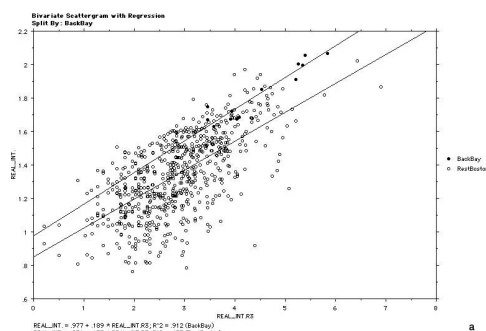


Figure 9a: Scattergram comparing the intelligibility of Beacon Hill with the rest of Boston

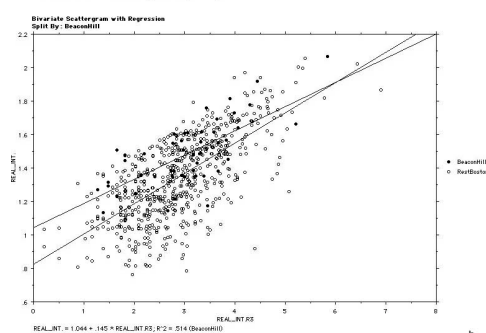


Figure 9b: Scattergram comparing the intelligibility of North End with the rest of Boston

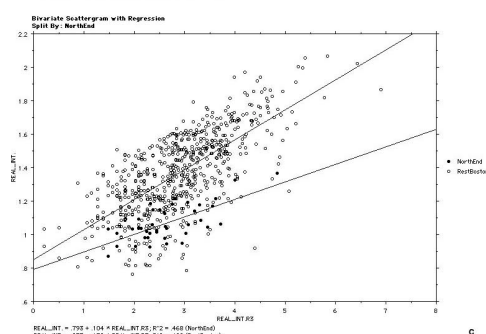


Figure 9c: Scattergram comparing the intelligibility of Back Bay with the rest of Boston

In contrast, North End, which has an almost uniformly low integration value at radius infinity, and, therefore, and lower intelligibility ($R^2 \sim 40\%$; Figure 9b) is an example of an introverted district—a district that offers very little sense of its connection to the city beyond its limits.

Backbay offers a contrast to North-End, in that it has extremely high values of intelligibility ($R^2 \sim 90\%$; figure 9c). This is confirmed by Lynch's findings as well. Overall, therefore, it can be hypothesised that all districts are marked by local intelligibility (all the three districts above reported *significant* predictability), but that the degree of predictability accounts for how well it affords orientating within the city.

6. Second order elements—bridging the concepts of the axial line and isovists

The second order elements are slightly more difficult to reconcile with the syntactic descriptions, especially in the case of urban settings, as these elements are not only predominantly visual, but also because they do not seem to be integrally related to the urban structure. Still, some potentially fruitful connections are suggested in the following section.

6.1 Edge

The definitions of an “Edge” according to Lynch are:

“Linear elements not considered as paths” (62)

“Boundaries between two kinds of areas” (62)

“[Edges are] visually prominent, ... continuous in form and impenetrable to cross movement” (62)

“Edges, whether of railroads, topography, throughways, or district boundaries, are a very typical feature...and tend to fragment [the environment].” (63)

“Edges are often paths as well”. (65)

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If we consider edges, which are *neither* paths *nor* the boundaries of districts, are there spatial and visual qualities to an edge, which are unique to the concept of an edge and are definable in terms of the spatial descriptors used in space syntax? Consider one of Lynch’s definitions of the edge, that edges are usually “Visually prominent,... continuous in form and impenetrable to cross movement” Let us consider what this might mean in terms of isovist properties. What are the attributes of an isovist, which could be “visually prominent,... continuous in form and impenetrable to cross movement”? Obviously, we are talking about surfaces bounding spaces, and to use Benedikt’s terms (Benedikt, 1979) we are distinguishing between the ‘real surface perimeter’ and those portions of an isovist’s boundary, the ‘occluding radials’, that constitute the rest of the isovist’s perimeter. If we imagine an isovist consisting of a high number of lines of sight radiating from a single point in space (‘isovist radials’), we can ‘unfurl’ the isovist and plot the distribution of its radial lengths. See Figure 10 for an example of three such isovists and the graphs showing the distribution of their radial lengths. An edge, in isovist terms can be defined as a specific property of the distribution of these isovist radials, namely where there occurs a smooth or uniform increase or decrease in the radial lengths. This is the case in the first two examples shown in Figure 10; these two examples illustrate isovists with visually prominent edges constituting a major proportion of the visual boundary. Where the chart demonstrates this characteristic of a regular rate of increase or decrease in radial lengths (the slope of a portion of the graph), then it can be held that there is a flat, occluding surface bounding the space. This is directly equivalent to Benedikt’s ‘real surface perimeter’.

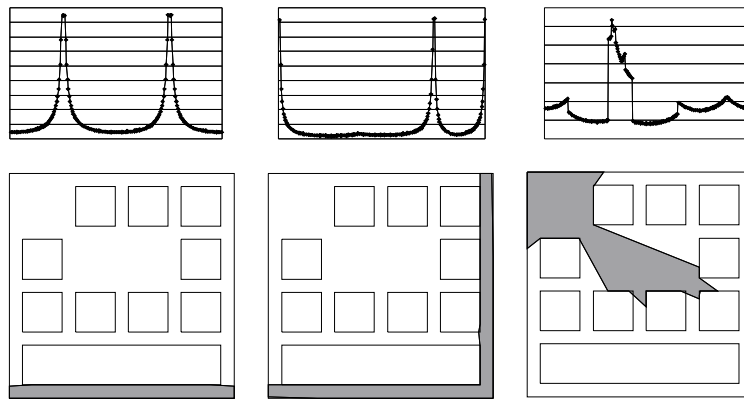


Figure 10: Graphs of 'Unfurled' Isovists: Left and Middle Isovists Indicating Strong Edges, Right Isovist Indicating a Weak/No Edge

Where there is a sudden 'jump' in the distribution of radial lengths in the graph, this indicates the presence of an 'occluding radial' in Benedikt's terms. This reflects Gibson's definition of an edge, "An occluding edge is usually but not necessarily projected as a... discontinuity in the gradient of binocular disparity (not when vision is with one eye)."⁹ This characteristic can clearly be seen in the rightmost example of Figure 10. The graph is not smooth and continuous, but is irregular and disjointed. A sudden increase in the radial lengths represents a line of sight that shoots past the corner of one occluding surface, continuing until it terminates at another occluding surface some distance from the first surface (a line in the 'all line axial map' and an possibly an E-partition). Since any edge can be defined as the real surface perimeter of an isovist, the question must be asked, what degree or amount of real surface perimeter constituting an isovist must be present for that edge to be perceived as a "visually prominent" boundary. We suggest that if a continuous section of an isovist's real surface perimeter constitutes a high proportion of an isovist's perimeter, then this would be perceived to be a *visually prominent boundary* or an 'edge' in Lynchian terminology.

59.17

In Lynch's Boston study, however, there seem to be very few edges, and this indicates that something more than their own visual property might come into play in determining whether visually prominent boundaries act as edges in a cognitive map. As Lynch points out, paths and boundaries of districts may often act as edges. In Lynch's maps of Boston, the subjects identify only two edges—the harbour to the east and the Charles river to the west and both are areas where the axial map ends abruptly. The only path that is picked-up as an edge is the elevated central artery, and that too only by his trained observers. Interestingly, this is also a situation of a sharp transition in the axial map. What is puzzling is that the water-front in the North End does not appear as an edge. Once again, the axial map provides clues for this phenomenon. There is no strong axial line *parallel* to the water-front here, as in the other two cases. In other words, the edge in an urban environment seems to depend to a great extent, not only on its own visual (isovist) properties, but where it occurs with respect to the main paths of movement (the structure of the axial map).

6.2 Landmarks

Landmarks, at least in Lynch's Boston maps, appear to be visible from the most significant streets, and there does not appear to be any relationship to the axial map at all. The primary quality of global landmarks is their ability to be visible over long vistas, but Lynch found that most such landmarks in Boston were 'bottomless'—they did not have any memorable connection to the paths network. Local landmarks are much better grounded and more used in planning routes, but they also tend to be very personal. Axial analysis, or even visual field analysis may contribute little to the identification of typical landmarks.

Although recent experiments in psychology (Darken and Sibert, 1993; Tlauka and Wilson, 1994; Magliano, Cohen et al., 1995; Darken and Sibert, 1996; Ruddle, Payne et al., 1997) show little evidence that people do actually use landmarks in the manner hypothesised by Lynch (external points of reference), landmarks too can easily be described in syntax and visual terms. In analyses conducted in the city of Corfu by Peponis and his colleagues (Peponis et al., 1998), they consider the visual 'catchment area' generated by the siting of churches in the dense fabric of the city. They recorded the areas from which a specific church may be viewed and examined the structural inter-relationship between them. Their conclusion was that there was structure to these regions of visibility, which differed from the axial structure: the isovists of the churches created a network permeating the entire city, whereas the axial structure prioritised specific roads and routes. They noted, however, that only a selection of these churches appeared to serve as landmarks and hence aid wayfinding, namely those with a particularly *idiosyncratic isovist shape*. Our hypothesis in this paper is that, personal landmarks aside, the inhabitants' '*consensus-landmarks*'¹⁰ are those whose visual catchment regions can be accessed from spatially integrated lines of movement, and have a distinctive isovist shape, as per Peponis' findings. Once again, our maps of Boston were inadequate to test out this idea, but this seems like a particularly promising line of inquiry to follow.

7. Concluding comments

7.1 The uses of the axial map: or objectifying Lynch's hitherto subjective representations

We have discussed how the axial map (supported with some visual field analysis) may prove useful in being able to explain, and by implication predict, the elements picked out within field studies both by inhabitants and trained observers. It appears that of the five categories of elements, three (paths, nodes, and districts) may have intimate links with the axial structure of the city. What role then, would axial analysis perform in studies of the visual image of the city?

As control for the “subjective” mapping of the city, Lynch sent out trained observers to construct, if not precisely an “objective”, at least a relatively systematic mapping of the city. He states that there were two main purposes for such a mapping: the first, to construct hypotheses to be tested in the verbal interviews, and the second, to develop a method for documenting the image of the city that would replace the tedious and expensive study involving several subjects, with one that was quicker and less demanding of resources, and still allowed a reasonable degree of prediction of the image of the city. He observes that while the method turned out to be remarkably good at accounting for the significant elements, it failed to capture the relationship between them. In his own words, “it was still too much concerned with single elements and underemphasised the relationship between them” (1960, 144). The axial map offers a good complement to the field documentation; it shows how the interrelationship between the visual elements can be taken into account, and is even more efficient in terms of resources and time than any field survey.

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7.2 Relationship between intelligibility and hierarchy

This paper examined the relationships between what we have termed first order elements (structurally distinctive) and second order elements (visually distinctive) demonstrating how both sets can be defined by Lynch and through space syntax terminology. In doing so, we increasingly observed that the dependencies connecting them did not suggest a mutual mapping. We conclude that there is a dependency of the Lynchian elements upon the basic space syntax spatial descriptors but no such dependency exists in reverse. This hypothesis can be summed up by the following statement: all imageable cities must be intelligible, but all intelligible cities need not be imageable (Figure 11).

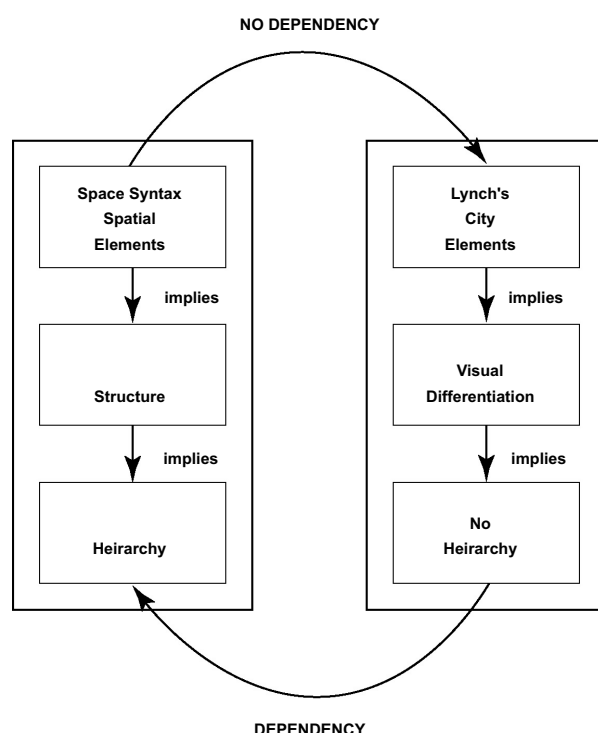


Figure 11: The Relationship Between Space Syntax and Lynch's Elements

The potential for visual differentiation arises and can only arise from an already existing structure and hence hierarchy of use. It is true, as Lynch claims, that a visually differentiated and ordered landscape (an imageable landscape) is characteristic of a functional city (as opposed to a dysfunctional or pathological one), but the visual differentiation can only arise from a well-developed structural hierarchy.

7.3 The cognitive element in space syntactical descriptions

This dependency of potential visual differentiation on spatial hierarchy, however, does not imply that Lynchian descriptions of the city can be simply reduced to syntactical ones. For, while syntactical theory is able to account for why many non-visually distinctive elements acquire prominence in inhabitants' images of their city, it has, so far, not made attempts to account for the selectivity itself, which is the key feature of the image of the city. Space syntax characteristically sorts elements (axial maps, convex spaces, and so on) along a continuum of values, and the syntactical image of the city includes all its elements; what Lynch's study points to is the need for a theory that offers a systematically attenuated or selective description of the city.

It could be argued that identification of the 10% integration core is one way in which this need is accommodated in space syntax. Such a core, for instance, could be seen as analogous to the 'skeleton' (a mental map of key paths constructed by wayfinding subjects) as described by Kuipers et al. (2003). In space syntax terms, the skeleton would consist of those paths that, due to their accessibility from the entire system, are more likely to constitute a substantial subcomponent of any route (given a high number of random origin and destination pairs). However, Kuipers et al. (2003, 82) pose the pertinent question, "Is there a qualitative difference between the skeleton and the rest of the map, or is the role of the skeleton an emergent behaviour of some uniform mechanism applied to the entire cognitive map?" In this respect, the approach of space syntax researchers and of Kuipers et al. must, by necessity, diverge, for space syntax researchers would view the skeleton as being intrinsic to the spatial configuration of the system (a given state), in contrast to the approach by Kuipers et al., where the skeleton is viewed as a phenomenon that emerges over time from the cumulative experience of navigating an environment. This example, and Lynch's study seems to suggest that such 'skeletons' may not be merely a matter of identifying the elements with greatest syntactical values, but may have structural features of their own.

A similar issue arises with the fact that inhabitants invariably ‘chunk’ their image of the city into sub-parts or districts, making it more amenable to the planning of routes, getting orientated, or giving and asking for directions. Again, our suggestion is that the syntactical structure of the city may be better seen not just as a single level structure of axial lines, but a multi-level or hierarchical one—a ‘structure of structures’ so to speak, in which the axial structure develops districts, and the inter-relationship between districts also has irreducible structural properties.

We, therefore, consider this paper not to be the fusion or overlap of two theories (Lynch theorising about elements but neglecting the underlying structure linking them and Hillier theorising about structure/syntax but choosing to omit the role of differentiated spatial elements) but rather an argument for the inter-dependency of both visually distinctive elements and spatial structures. We have discussed how each is essential to the other; namely that we are able to identify individual elements only by the fact of their relationship to each other and to their context (i.e. the structure permits the recognition of elements) and that the occurrence of more than one element will immediately form a structure of relationships between them (i.e. any set of elements are by necessity structured). Due to the essential visual nature of Lynch’s five elements, such a strong interdependency implies that space syntax is effective as both a set of theories and a family of methods precisely because it has an inherently cognitive basis.

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Notes

¹ Kuipers et al.’s definition of the skeleton is a subset of paths within a complex environment that is used with greater frequency than the rest of the paths and therefore serves as a mental frame of reference in environment cognition.

² Re-definitions of edge, district, node, path and landmark will form a substantial part of this paper and will use a variety of spatial representations, ranging from axial lines to isovists. By drawing together all of these spatial definitions and demonstrating how they might be derived from each other computationally, we can begin to create a unified ‘syntactic redefinition of Lynch’.

³ The term ‘projection polygon’ has been used to define isovists generated at heights other than eye-height, e.g. foot level (indicating direct accessibility).

⁴ In conversations with N. Dalton, B. Hillier, A. Penn, A. Turner and J. Peponis.

⁵ Although this might result in a line that would not strictly be a line of sight, namely that it could pass through an occluding surface.

⁶ i.e. axial lines are defined via the definition of convex spaces, which can be defined via VGA analysis, which in turn can be seen to be a sub-set of the all line map (pairs of mutually visible lines).

⁷ The axial analysis was performed using a combination of Spatialist v.1 (copyright Georgia Tech Research Corporation), and Axman v. 22.5 (copyright University College London and Nick Dalton).

⁸ The frequency range refers to the number of times it was identified in Lynch’s study, and is read from the symbols that Lynch uses to depict these roads in his descriptive maps.

⁹ From Optical Occlusion and Edge-Information in an Optic Array, by J.J. Gibson, March 1967, <http://www.ksu.edu/psych/farris/gibson/files/occlusion.html>

¹⁰ Landmarks that can be agreed to be such by a large number of a district’s or city’s inhabitants.

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