# Is Spatial Intelligibility Critical to the Design of Large-scale Virtual Environments?

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**Abstract**

*This paper discusses the concept of 'intelligibility', a concept usually attributed to the design of real-world environments and suggests how it might be applied to the construction of virtual environments. In order to illustrate this concept, a 3d, online, collaborative environment, AlphaWorld, is analyzed in a manner analogous to spatial analysis techniques applied to cities in the real world. The outcome of this form of spatial analysis is that AlphaWorld appears to be highly 'intelligible' at the small-scale, 'local neighborhood' level, and yet is completely 'unintelligible' at a global level. This paper concludes with a discussion of the relevance of this finding to virtual environment design plus future research applications.*

## Introduction: what carries across virtual & real space regarding intelligibility?

Increasingly, large-scale virtual environments are being created for everyday, social uses. Such environments may be designed through a 'top-down' process (a centralized design-intent, used to produce, for example, collaborative, online gaming worlds) or designed through a 'bottom-up' process, such as the Activeworlds' environment, 'AlphaWorld' (constructed in a piecemeal manner, over time, by a heterogeneous user-base). Other types of virtual environments may be produced 'automatically' either to visualize large-data sets (Ingram and Benford 1995; Ingram and Benford 1995; Ingram, Bowers et al. 1996; Ingram and Benford 1996; Ingram 1997) and (Chalmers 1995) or to automatically generate urban-like environments for other purposes (Parish 2001). Regardless of how these environments are designed ('top-down', 'bottom-up' or using a rule-based, automated procedure), they are, for the most part, intended to be utilized by a specific user-base, a community of users. The question, which this paper begins to address, is what are the design criteria necessary, such that these virtual worlds should be comprehensible, easily navigable and memorable (with respect to repeat-visits), or as researchers within the architecture community would term it '*intelligible*'.

As Darken says in his introduction to the 1999 special edition of the journal Presence, (Darken, Allard et al. 1999), *"Few things are as fundamental to the human experience as the interaction between humans and their environment - be it physical or virtual."* Later, in this same editorial, Darken and Allard go on to stress the nature of research into virtual navigation by stating that, *"In our attempt to make better interfaces for virtual environments, we must understand what carries over from the real world to the virtual world."* These research aims are echoed in (Ruddle, Payne et al. 1998), when they say, *"research should address the navigation of VEs per se as well as the transfer of spatial knowledge learned in VEs to the real world."* It is also pertinent to be reminded of Passini's observation about wayfinding in the real world (Passini 1992). He stresses, *"Although the architecture and the spatial configuration of a building [ditto for virtual environments] generate the wayfinding problems people have to solve, they are also a wayfinding support system in that they contain the information necessary to solve the problem."*

## Lynch, 'legibility' and virtual environment design

In (Lynch 1960) a definition of 'legibility' is suggested, this being, *"The ease with which [a city's] parts can be recognized and can be organized into a coherent pattern... a legible city would be one whose districts or landmarks or pathways are easily identifiable and are easily grouped into an overall pattern."* A number of researchers have used the ease of computer-generated theoretical environments to facilitate investigations into the effects of the environment on patterns of navigation, and in particular to test out Lynch's hypothesis that landmarks are necessary visual cues to aid wayfinding (the five key components being paths, edges, landmarks, nodes and districts). Little conclusive evidence was found to support Lynch's ideas. However, a number of researchers went on to suggest how the inclusion of not only landmarks, but also paths, nodes, districts and edges could render virtual worlds more intelligible and hence prevent disorientation in large-scale (and especially abstract) virtual worlds.

In Magliano's paper, (Magliano, Cohen et al. 1995), they consider the impact of the wayfinding goal (the destination in any wayfinding task) on wayfinding performance. This experiment was conducted within a virtual simulation (in this case a simulation comprising a series of still images forming a walkthrough a small town). The extent of subjects' spatial-knowledge acquisition was measured after observing the pictorial walkthrough. Before the experiment, different instructions were given to subgroups of the participants. They were instructed to: either attend to possible landmarks, to the route itself, or to the spatial configuration of the small town. A control group was given no such instructions. Subjects' spatial knowledge was assessed by varying tests, which were applied to each group. Magliano et al. concluded that the subjects who had been given the instructions to learn only the landmarks did no better in the memory tasks than the route or configuration learning groups. The main distinction between the groups occurred during a direction-giving task. The subjects who had attended to either route or configurational information gave better (more accurate information) than either the control group or the landmark group.

This result suggests the relative unimportance of landmarks, leading to a set of papers, all of which use virtual environments to assess the impact of landmarks on wayfinding, with widely differing results. Lynch originally suggested that landmarks played a significant role in our cognition of the environment, in (Lynch 1960). Magliano's paper above seemed to suggest that for environment learning, landmarks had no effect upon a subject's spatial knowledge. This lack of evidence for any landmark effect is supported in the next two papers. The first of these is (Tlauka and Wilson 1994).

Tlauka reported upon an experiment in which subjects were required to learn their way through a sequential series of rooms (linked by two doors, one always 'locked' the other 'unlocked'), in a virtual simulated environment. For one group, memorable landmarks were placed in the environment to aid navigation by providing visual cues. For a second group, no such landmarks were present. No noticeable difference in task performance was found between the two groups. This unexpected result was explained by Tlauka and Wilson, in terms of strategy. They hypothesized that in the landmark case, room-landmark pairings were learnt, while in the non-landmark situation, sequences of right/left choices were memorized. They maintained that landmarks do contribute to navigation, but as only one of many navigational strategies used. They judged that the true effect of landmarks upon navigation can only be accounted for by sufficiently suppressing all other strategies or techniques. They then attempt to do this in an additional experiment (in which the R/L sequence-learning strategy is suppressed through the imposition of a simultaneous counting-backwards task). Again, there was no measurable effect of landmarks upon performance. Despite a result at odds with their expectations, they do, however, praise the utility of computer-simulated environments in the accurate testing of such navigational aids.

In Ruddle's paper (Ruddle, Payne et al. 1997), they investigate the effects of landmarks on route-learning ability and other spatial cognition tasks. They find a slight improvement in the time taken to complete the task in the environment containing landmarks in contrast to the environment without landmarks. However, when performing distance and orientation estimates, the effect of the inclusion of landmarks in the environment appears to be negligible. In contrast to this outcome that only weakly suggests that landmarks play any role in wayfinding, the subjects report in questionnaires that they actively used the landmarks, particularly in forming associations with specific locations in the world. The weak (as opposed to significant) effect of the landmarks appears to support the findings in Tlauka and Wilson and Magliano's papers.

In (Darken and Sibert 1993) and (Darken and Sibert 1996) the effects of landmarks on time taken to reach a wayfinding goal and on distance/orientation estimates were small. However, of all the differing navigational aids used in their experiments (landmarks being one such aid), some were of more use than others. Although it was not found that local landmarks significantly aided navigation, the inclusion of a virtual 'sun' as a global landmark did appear to improve performance. This distinction between local and global landmarks is subsequently addressed in a paper by Steck and Mallot (Steck and Mallot 2000), which provides the strongest evidence for the importance of landmarks to navigation.

Steck and Mallot's paper puts forward compelling evidence for the use of landmarks and describes a pair of particularly well-constructed experiments designed to investigate the dual effect of local and global landmarks. One of the techniques employed in this paper was to alter the relationship between the local and global landmarks, after the subjects had already navigated once through the environment, hence creating a conflict of cues. They concluded that some subjects used local landmarks, others global landmarks and others a combination of the two, whilst some people alternated between using local and global cues. The overall conclusion of this paper is that there appeared to be evidence that landmarks were being used by people when finding their way. Since this contrasts with earlier work (which shows only a weak effect of landmarks), it may well be that landmarks do play a role. It is likely that this is only one type of environmental cue used when navigating. However, Steck and Mallot also conclude their paper by endorsing the usefulness of virtual environments for this kind of research, particularly for the ability to create *"conflicting environments"*, i.e. nonrealistic environments - in this case, worlds in which environmental cues shift between subsequent journeys. They say *"Virtual environments are a valuable tool for navigation experiments, both for consistent and inconsistent environments."*

Another component of environments hypothesized by Lynch to be crucial to wayfinding is the path (the full set being paths, edges, landmarks, nodes and districts). The use of paths in virtual worlds is investigated by Darken and Sibert in (Darken and Sibert 1996). In this study, subjects were required to perform a naïve search task in a large-scale environment representing open sea and islands. The subjects were searching for targets (ships) and the experiments took place in five different virtual (sea/island) worlds. Each task in each world was attempted under a number of conditions (with the aid of a grid, a map and both a grid and map). Darken and Sibert conclude that disorientation arises from a lack of directional, visual cues. Another unexpected observation they make is that they surmise that path-following is a natural human spatial behavioral characteristic, to such an extent that even when an explicit path is not evident, other environmental features such as coastlines or gridlines were used as implicit paths. This same experiment is described in more detail in (Darken and Sibert 1996), where the effects of grids (pseudo-paths) on wayfinding is that they appear to significantly improve performance. They surmise that grids are useful for providing useful orientation/ directional cues.

These papers' focus upon attempts to find an empirical justification for the environmental components identified by Lynch, have led a number of researchers to attempt to use these principles in the design of virtual worlds. This next set of papers briefly examines research that has addressed issues of wayfinding in virtual worlds, but with the aim of improving virtual environment design. A large proportion of these papers have directly implemented Lynch's concepts of paths, edges, landmarks, nodes and districts as design principles for virtual world design.

For example, one such an application of Lynch-inspired design principles is the approach taken in a series of papers by Ingram and Benford (Ingram and Benford 1995; Ingram and Benford 1995; Ingram, Bowers et al. 1996; Ingram and Benford 1996; Ingram 1997). In these papers, the authors are particularly concerned with the design of abstract data-spaces and how to make them easily navigable. They examine methods to insert paths, edges, landmarks, nodes and districts into their world designs. Using their "LEADS" system, districts, landmarks and edges are computed from the spatial distribution of the data, they claim to aspire to being able to evolve paths from the movement of the users over time. Nodes are then formed by the intersection of paths. In the absence of being able to achieve path evolution at the time of their writing, paths are instead inserted into the world using computed methods.

The main problem that they encountered with this approach concerned a conflict between traditional 'paths' and the six degrees of potential movement available in the type of environments they are using. However, on the whole, they found that subjects performed wayfinding tasks in less time with repeated exposure to the "LEADS"-enhanced environments compared to plain environments. The subjects also claimed to feel less disorientated in the "LEADS"-enhanced environments. In a later paper, they also discuss space syntax research (Ingram and Benford 1995), which leads them to conclude that the "subtle interrelations between access, lines of sight, navigability and probabilities of social encounter can be exploited in the implementation of suitably designed or evolved virtual villages, towns and cities... in this way city (etc.) metaphors for virtual environments may produce gradients of accessibility for information" In other words, they speculate that the use of city-like environments may serve to be useful metaphors when designing navigable abstract worlds. Ingram and Benford finally express a desire to combine both space syntax and Lynch-inspired approaches to aid navigation in future work on virtual worlds design.

Another important paper is that of Charitos (Charitos 1997) in which he proposes using Lynch-like components to aid navigation in the virtual world. His paper begins by describing possible examples of types of virtual landmarks, signs, boundaries (edges), thresholds (edges), places, paths, intersections (nodes) and domains (districts). Unfortunately, unlike Ingram and Benford, he makes no attempt in this paper to test the effectiveness of these objects on wayfinding task performance. The approach described in this paper remains conceptual only.

Finally, in (Darken and Sibert 1996), Darken also attempts to use some of Lynch's principles in order to investigate their effect upon wayfinding (this is in addition to his earlier work on landmarks and grids). In particular he suggests dividing the environment into smaller parts (districts) and ordering these parts using an organizational principle, such as a road network or an underlying grid. The conclusion reached by Darken was that *"the presence of the wayfinding augmentations did significantly improve searching performance."* Although as a device, this was less useful than the provision of a virtual map. He ends this paper by noting that *"Although not all wayfinding augmentations are appropriate for every problem, this research begins to show what types of information are most important, how they can be provided, and how they might be used. This is the first major step toward a methodology for designing navigable virtual worlds."*

**Space, configuration and 'intelligibility'**

Although Lynch has proved to be an inspiration for many researchers interested in the problem of designing intelligible virtual worlds, there is another school of thought, which is particularly relevant to issues of virtual world design. This is the field of research is known as space syntax. Space syntax is a family of theories and methodologies concerning the social use of space, which grew from research at University College London in the mid-1970s onwards. From the very beginning, Space syntax research focussed on the relationship between space and social life, be this the social life of a simple building, a complex building (or set of buildings), a settlement or an urban district (Hillier and Hanson 1984) and (Hillier 1992, 1996) or as this paper will attempt to demonstrate, collaborative virtual environments. Essentially, it may be argued that in an intelligible system, natural movement (that is movement from everywhere to everywhere else) will tend towards certain spaces and streets allowing potential for chance encounter and social interaction (Hillier 1992). The key difference between Lynch's concepts of 'legibility' and 'imageability' and the concept of 'intelligibility' can be held as being a distinction between the overall structure of an environment versus its constituent elements. Lynch was essentially suggesting that it is the presence of certain elements within an environment (paths, nodes, edges, landmarks and districts) which are of greatest import (to wayfinding, forming internal representations of environments and designing 'memorable' places). In complete contrast to this, the concept of 'intelligibility' maintains that it is the *structure* of an environment which is most important and specificially the relationship between local and global elements.

A relevant definition of an intelligible environment is given in (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 above definition of intelligibility concerns the relationship between the local visual cues (e.g. connectivity of a space - how many other spaces can be accessed from that 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 navigating efficiently. 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, people become lost and disorientated. In (Conroy 2001) conducting research into patterns of navigation in intelligible and unintelligible worlds, it was noted that users appeared to make use of local, visual cues in virtual worlds in a manner similar to our behavior in the real world. However, although Hillier's definition of *"intelligibility"* is elegantly succinct, it is quite narrow in its focus and could be expanded upon to produce a more general definition of intelligibility, which will be the definition proposed by this author. An expanded definition of intelligibility proposed by this paper is as follows, for an environment to have an *"intelligible"* structure, this implies a structure, of which it is relatively easy to form an internal (or mental) representation, and which can be easily retrieved and/or communicated to others. Although focussing less on the relationship between local and global structures, this definition still places the emphasis upon the structure of (or relationship between) spaces, rather than individual elements within an environment. The relationship between intelligibility versus local and global structures will be explored in the next section, in the context of a particular, online collaborative, social environment, AlphaWorld hosted on the Activeworlds' server.

**The relationship between local and global structure in 'AlphaWorld'**

One method used by space syntax researchers to represent the spatial structure of cities, is to model the network of streets, represented as 'axial lines', or the *fewest and longest lines of sight that pass through every space in the system.* These lines can be thought of as lines of potential movement, and where they cross as changes in direction of navigation. From this simple (and efficient) representation, a graph is produced, in which each line of sight is represented as a single node in the graph, and any two intersecting lines are represented as an edge linking those two nodes in the graph. The average number of steps (in the graph) is calculated, from each node to every other node in the system (this calculation is performed for each axial line or node constituting the system). Those lines that are, on average, a shorter number of steps from all other lines (or fewer number of changes of direction) are termed more 'integrated' within the system. Whereas those lines that are a greater number of steps away from all others are termed 'segregated'. In real cities and environments, it has been repeatedly observed that more integrated lines tend to have a larger proportion of pedestrian movement along them than the more segregated lines. This relationship has been demonstrated to be statistically significant over a wide range of different cities, urban areas and complex buildings. These results can be visualized by coloring the axial lines according to their average depth in the system. As a real-world example, the axial structure of downtown Atlanta, Georgia is illustrated in figure 1.0 below, with those axial lines which are on average a short number of steps from all others being colored red and those lines which are very segregated within the system are colored blue (axial map courtesy of M.Major).

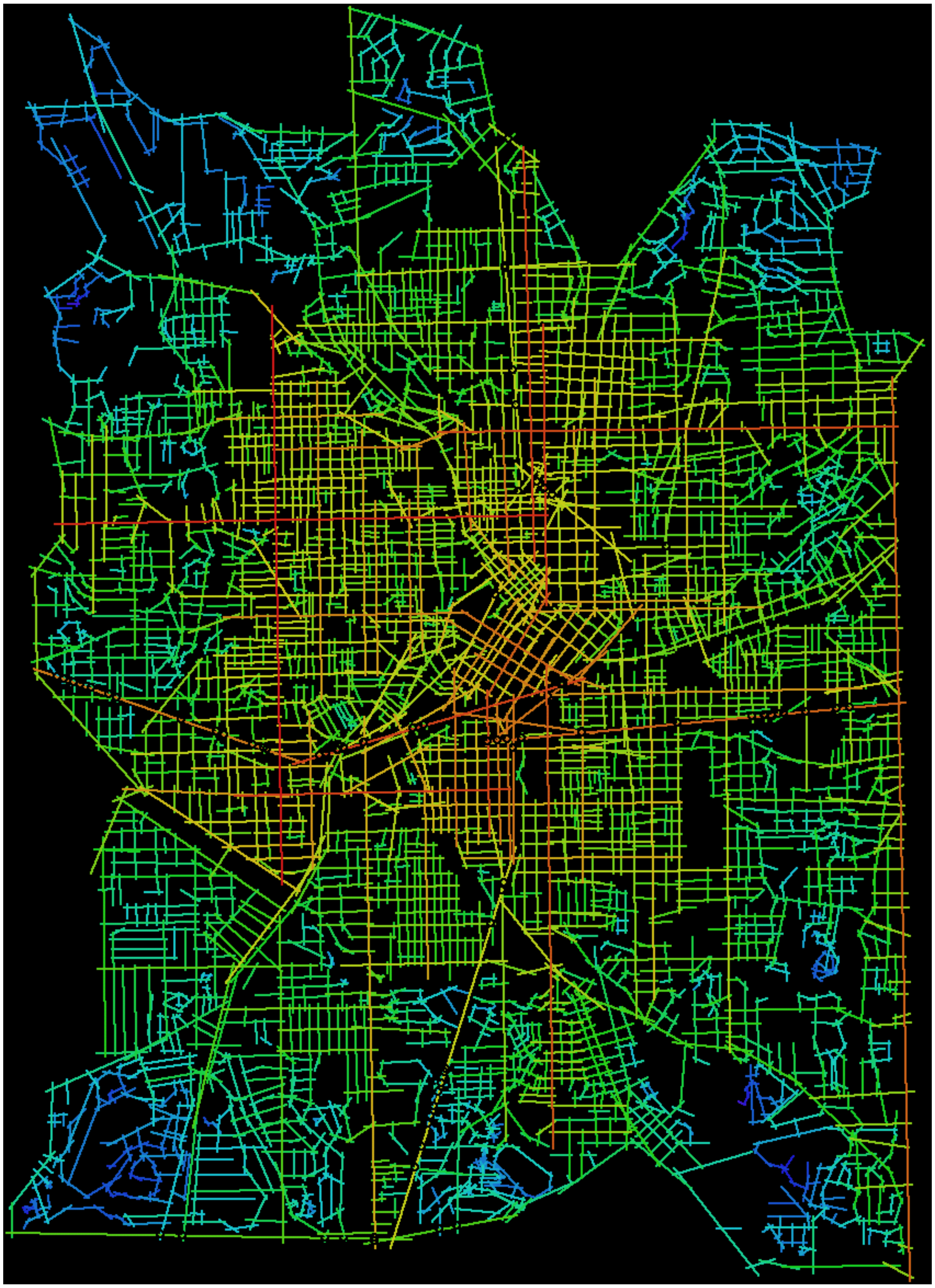

Figure 1.0 Axial Structure of Downtown Atlanta, Georgia

Click here to view the axial structure of Atlanta as a VRML file (enabling zooming in to examine subareas in more detail and to pan around parts of the axial structure).

The example environment used in this paper to explore the concept of intelligibility with respect to a virtual world, is the 3d, web-based, collaborative world, known as AlphaWorld. AlphaWorld is the flagship 'virtual city' of the company, Activeworlds. In their own words, they describe it as a world *"Which consists of virtual real estate on which users can create virtual structures using objects from our library of more than 3,000 objects and textures. As of October 26, 2001, users had placed more than 100 million building blocks on AlphaWorld".*

Batty et al. were particularly fascinated by AlphaWorld in (Batty 1998), they describe it as *"Essentially an urban world where the emphasis is on the ownership of land and where a city structure has clearly grown up"*. It is the apparent *structure* implicit in the plan of AlphaWorld, which Batty et al. find so compelling, in particular the observation that AlphaWorld appears to have both a Central Business District ('Ground Zero') and a radial structure extending from center to edge, in a manner, which at first glance, appears to mimic the structure of real city development (along major arterial routes). They go on to say *"What is remarkable about these virtual worlds is the morphology mirrors in some sense real cities."* Below in figure 1.2 is illustrated a 'satellite' image of AlphaWorld, generated August 1999 by Roland Vilett (Copyright 1999 Activeworlds.com, inc.). Again, in Activeworlds' own words, they describe the apparent spatial distribution of the 'buildings' and 'streets' of AlphaWorld, *"You can see the "starfish" shape of building as people crowd their buildings along the North-South axis and the "equator" of AlphaWorld, and as they build along the coordinates with matching numbers. (I.e. 200n 200w, 450s 450e, etc.) Some do this so that their coordinates are easy to remember, and others are simply building onto what others have already built."*

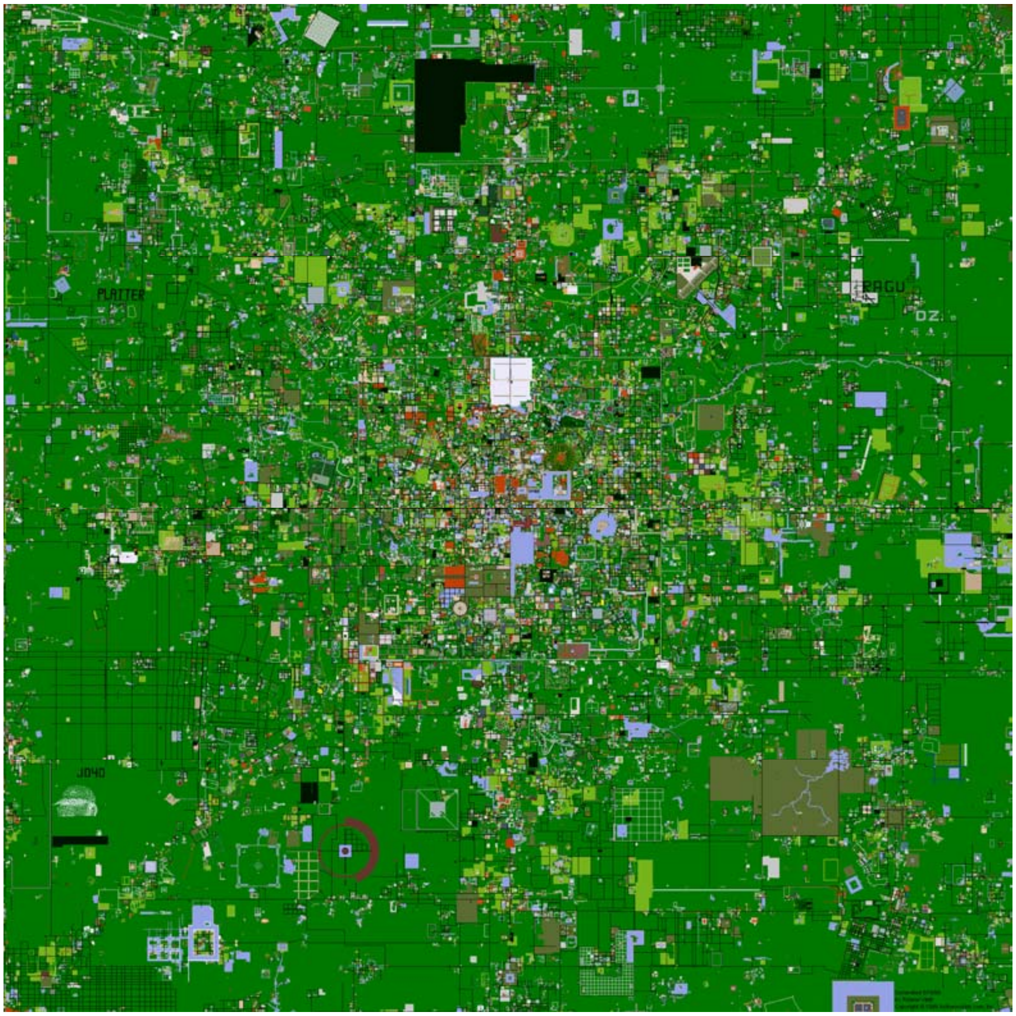

Figure 1.1 'Satellite' image of AlphaWorld on the Activeworld Server (1999)

(pass your mouse over the image to view the "structure" of AlphaWorld)

The first problem, which it would be necessary to address, in order to examine the relationship between local and global structures and the concept of intelligibility in the specific case of AlphaWorld, is whether it would be possible to apply the same kind of spatial analyses used to represent the street structure of the city of Atlanta, to the virtual city of AlphaWorld? Secondly, were this possible in principle, how would it be achieved in actuality (how would methodologies applied to real-world environments need to be adapted to analyze virtual spaces), and finally what would be the significance of analyzing a virtual environment in this manner, if any? The first problem, as asked above, is whether it could be possible to apply the same method of analysis, which was used to produce the map of Atlanta in figure 1.0. In the case of Atlanta, the fewest and longest lines of sight that pass through the spatial system, were represented as single lines on plan. However, in the city of Atlanta, vehicular movement, and to a lessor degree, pedestrian movement, are confined to the street structure, so that there exists a strong relationship between lines of sight and lines of potential movement. On the whole, they are one and the same. In AlphaWorld this is not the case. Not only is it possible to move anywhere within AlphaWorld (movement is certainly not restricted to the street structure), it is also possible to to move transspatially, to 'teleport' from one location to another in an instant. This is achieved by typing in the coordinate location of an 'address', at which point the user is transported to the new location, without the necessity to move through the intervening spaces.

Figure 1.2 Quicktime Movie of a 'Street' Scene in AlphaWorld

However, since AlphaWorld is a metaphor for a city, and citizens are indeed engaged in the construction metaphorical 'streets', see figure 1.3 below, *even if* there are no 'cars' to travel down them, then this produces a spatial structure of sorts, one which could be analyzed. Were one to attempt to analyze only the spatial structure of the 'streets' in AlphaWorld, what would one actually be mapping or representing?. This paper will argue that by producing a representation of the street-structure in AlphaWorld (in the same manner as a real city), that this would be akin to mapping a metaphor. Why should the structure of something so intangible be of interest in the context of design intelligible virtual worlds? Because, as users, we assign a meaning to 'streets' whether or not they are actually used in a manner that is 'street-like'. As a community of users, we see a virtual street in a virtual world and by association with its real-world meanings we assume (occasionally erroneously) that it must lead to some kind of 'destination'. Many citizens, building in AlphaWorld for the first time, seek out an empty plot of land, adjacent to a street, such as the location illustrated in figures 1.3 and 1.4 below, and then proceed to develop their plot, accessed from the 'highway'. (In fact, such development is actively encouraged. Since any development in AlphaWorld requires a 'seed' object, the online guide for first-time builders recommends finding unclaimed land adjacent to a 'highway' and cloning part of the highway as the 'seed' object with which to begin building.)

Figure 1.3 A Typical 'Highway' (Undeveloped) in AlphaWorld

Figure 1.4 Quicktime Movie of a 'Highway' (Undeveloped) in AlphaWorld

In order to analyze the street-structure of AlphaWorld, a few modifications were needed to be made to extend the techniques commonly used in the real-world. First, the streets were isolated from the 1999 'satellite' image of AlphaWorld. This was able to be achieved through the fact that all streets are constructed of the same basic building-blocks (see figure above), and hence are the same color on the satellite image. Rather than using an automated process of edge-detection, the 'axial lines' were drawn by hand, as this was felt to be more accurate, having less margin for error. However, unlike a real city, the 'street-structure' of AlphaWorld is discontinuous. In a real city, there are no streets that are inaccessible from the system as a whole, the network is continuous. In AlphaWorld, certain neighborhoods may be developed, which are not connected to their adjacent neighborhoods. Since the software being used to analyze the network of connections of the lines assumes a single system, or connected graph, then it became necessary to link any disconnected subsystems to the main structure. This was satisfied by applying a simple heuristic; if a subsystem or neighborhood is disconnected, then it should be connected to an adjacent system through the extension of the longest line in the subsystem, that can make the connect in the least possible distance. Clearly, this requires a certain degree of judgment (between longest lines versus shortest distances) on the part of the person drawing the lines. The resulting structure contains in excess of 11,000 axial lines, which compares to London with approximately 18,500, Metro Atlanta (figure 1.0) 3,200 lines and Washington 3,500 lines. Once again, as in the analysis of Atlanta, a graph representation of the structure of the lines is produced and the resultant values of 'average step depth' or 'integration' are calculated. Those lines that are shallow to the system as a whole are colored red, whereas those lines that are deep within the structure of the system (many steps in the graph) are colored blue. The results can be seen below in figure 1.5 and should be compared to the earlier axial map of Atlanta in figure 1.0. Both axial maps may be viewed as VRML files allowing for interactive zooming and panning, accessed by following the links beneath figures 1.0 and 1.5.

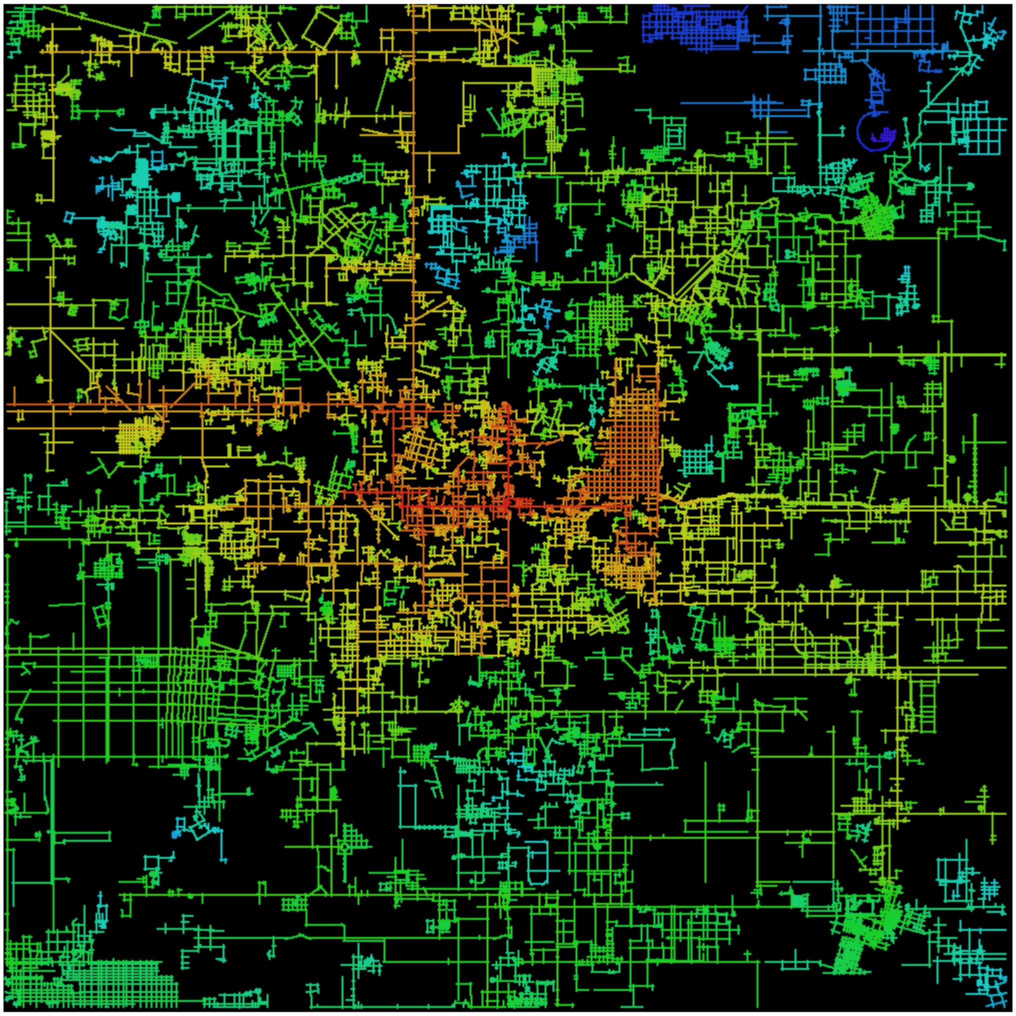

Figure 1.5 'Axial Structure' of AlphaWorld

Click here to view the axial structure of AlphaWorld as a VRML file (enabling zooming in to examine subareas in more detail and to pan around parts of the axial structure).

The main difference between the overall structure of Atlanta compared to the structure of AlphaWorld can be seen in the pattern of the most integrated streets, those colored red on the two maps (figures 1.0 and 1.5). In Atlanta, there are a number of highly-integrated lines which connect the center of the city to the edge of the city. This network of major integrators provides the city with a superstructure, an overall global structure connecting local neighborhoods together. Compare this with the map of AlphaWorld, where there are only a couple of highly integrated lines that extend towards the outermost boundary of the system. On the whole, in AlphaWorld, the center is highly integrated and the boundaries quite segregated within the system. In noticing this phenomenon we are already beginning to uncover the relationship between the globally integrating lines and local sub-areas. Now, let us return to the definition of intelligibility from (Hillier 1996), in which he says, *"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."* One way of exploring this is to compare the relationship between the integration value of an axial line and its connectivity (how many other lines it connects to). For an intelligible system we would expect there to be a good relationship between these two values.

Below are presented eight sub-areas or neighborhoods from AlphaWorld, removed from the system and analyzed as separate spatial structures. They are labeled A-H and are illustrated both on an interactive map as well as a 'static' printer-friendly version (both accessed below). They are selected from different parts of AlphaWorld and vary both in size and number of lines, the smallest (in geographic area) being sub-area 'C' and the largest being sub-area 'F', which can be found in the Southwest corner of the map. Also presented below are the scattergrams produced by plotting the integration values of the axial lines constituting the subsystem against the connectivity values of those lines. On the printable version, they are arranged in descending values of r-squared, or from the most to least 'intelligible'. However, in terms of the kinds of values (or values for r-squared) which we would expect to find in a real city, all of these neighborhoods are quite intelligible. This is, broadly speaking, not unexpected, since each neighborhood is the product of a deliberate design intention, designed by an individual or small number of individuals, constructed at ground-level. At the local level, it is common-sense, that these should be intelligible structures. However, how do these neighborhoods fit into the global structure of AlphaWorld, if at all?

Click here to view an interactive map of the subareas showing their intelligibility

Click here to view a printable version of the subareas showing their intelligibility

If we perform the same exercise, of plotting the values of integration against the values of connectivity for all the lines in AlphaWorld, we can plot another scattergram. This should be an indication of how intelligible is the spatial structure of AlphaWorld as a whole. The results can be seen in figure 1.6 below. The r-squared value for all the axial lines in AlphaWorld is 0.0054, in other words, there is practically no relationship between how connected a line is and how integrated it is with the overall structure of the world. A highly connected line could be very segregated, whereas a line that may be well integrated might not be as highly connected as one would imagine. Therefore, by Hillier's definition, AlphaWorld is an unintelligible system, albeit one composed of highly intelligible local neighborhoods, connected with no overall global structure or 'super-grid'.

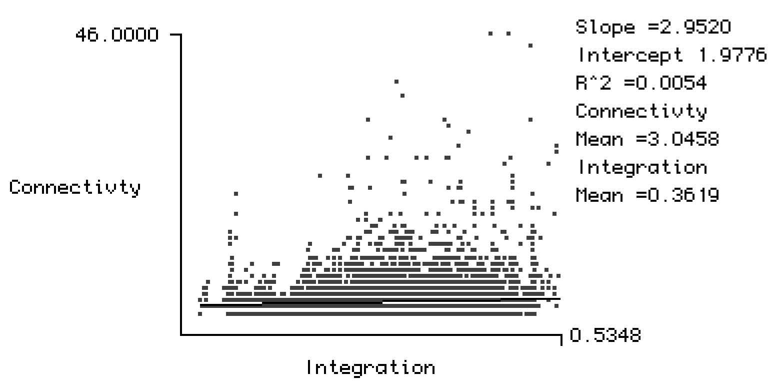


Figure 1.6 Relationship Between Integration and Connectivity Values for the Axial Structure of

**Conclusions**

This paper has discussed attempts to understand how we find our way through virtual environments and what factors may contribute to the design of environments that are easily navigable. It continues by discussing a number of applications of ideas from Lynch about how to create virtual environments that have a high degree of 'legibility' It goes on to argue that 'legibility' is not as important as the concept of 'intelligibility' defined by the author as the need for a spatial structure which is easily retrievable/communicable and defined more specifically by Hillier as the relationship between local visual cues and global spatial structures. A 3D, collaborative, online virtual environment was subsequently analyzed in a manner consistent with analyses of the spatial structures of real cities, in order to determine how intelligible its structure. Although at the level of the local neighborhood, this environment appeared to be highly intelligible, overall (and hence by Hillier's definition) it must be considered to be extremely unintelligible; this environment being one which contains no unifying superstructure.

However, why should it be important to design worlds which have an intelligible global structure when that global structure need not be used for navigation, as is the case with AlphaWorld? The argument that this paper is putting forward, is that the fact that navigation is not contiguous in this environment does not preclude a requirement for an intelligible global structure. Consider one of the definitions of intelligibility put forward in this paper, that is, for an environment to be considered intelligible it should have a structure, of which it is relatively easy to form an internal (or mental) representation and which can be easily retrieved and/or communicated to others. This definition may apply equally to the structure of a local sub-area or to the environment as a whole. The very fact that movement in these environments can be discrete (noncontiguous) surely implies that there is a *far greater need* for these environments to be intelligible. If it is possible to simply 'teleport' to a destination, without the need to move through *any* intermediate spaces, then upon arriving at a location, it is of uppermost import that at the local level, the neighborhood be intelligible (which in AlphaWorld it is). However, how much more informative would it be, if the environment were also globally intelligible? Imagine, that upon teleporting to a location, it were not only evident how one should navigate around the local area, but you were equally aware of your location within the overall structure (as per Hillier's definition). This is essentially an argument for intelligibility as 'context knowledge' rather than navigational aid. This paper will conclude by suggesting that perhaps if AlphaWorld were to have a more intelligible global structure, there would be less of a need to 'teleport' from location to location and perhaps a greater opportunity for social interaction. The questions which arise directly from this are whether there are types of exploratory behavior which are dependent upon spatial structure and whether there is a social benefit associated with such behaviors? Does more virtual 'walking' correlate with more social contact, i.e. more 'friends' (certainly if a user always 'teleports' from location to location the potential for chance encounters is significantly reduced). Equally, it would be informative to gather ethnographic data on the user-experiences of the community base of such an environment. In particular, it would be useful to determine whether an analysis of the spatial structure of the environment appears to reflect the experiences of the users.

This paper, has made a tentative effort to illustrate how concepts and techniques applied to the analysis of real-world cities may begin to be applied to the design of virtual environments. However, there is a need for considerable research into exactly how the family of theories and methodologies known as space syntax could be sufficiently expanded in order to permit a greater understanding of how we navigate through and interact with virtual environments. It could be further argued that if the functions of such large-scale environments are predominantly social (which the majority of them are) then the need for such techniques is all the greater. Eventually, it is envisioned that these techniques might allow a set of 'good-design' guidelines to be developed, aimed specifically at the design of 3D virtual environments which are intelligible and easily navigable.

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