Solutions for visibility, accessibility and signage problems via layered graphs

Conference or Workshop Item

Solutions for Visibility Accessibility and Signage Problems via Layered Graphs

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Abstract

One of the rare representational problems encountered during the construction of axial representations of architectural configurations in space syntax is the so called 'visibility accessibility problem'. This is the condition when it is possible to perceive a space but not be able to directly traverse to that space. This condition arises in a number of cases for example in an office with half height partitions, or glass walls, in an urban street where safety barriers prevent free pedestrian movement or in a multi-storey building with an atrium which permits the direct perception of spaces on the second or story but not provide direct access to them.

This paper introduces a new spatial representation called the multi-layered network that is asserted to be a more general representation of topological spaces than previous representations. Proofs are argued for certain aspects of the representation that is based as an extension of current topological representations and computations. A software implementation of this representation is demonstrated with a number of examples from the problematic cases. Finally it is argued that this new multilayered representation could also be used as the basis for a spatial representation which included signage and so by extension could make testable conditions that could measure the effect of differing types of signage in a building context.

Introduction

Space syntax (Hillier and Hanson 1984; Hillier, Penn et al. 1993; Hillier 1996; Hillier. B 1999)has proven to be a powerful predictor of movement at the urban level and capable of giving a great deal if insight at the building level. One problem discovered when mapping buildings is might be known as the visibility accessibility problem. That is how to construct an axial representation of a building where elements of the building can be seen but not directly accessible. One example of this is an office building, or with an atrium – a large open space in the building allowing one to see up and observe a space exists on the second floor but does not afford direct access to it (for example by a directly visible stair case, escalator or lift/elevator) see Doxa(Doxa 2003) and Parvin(2008) for examples. While it could be argued that these kinds or spaces are rare and can be handled by adhoc means it is the contention of this paper that this phenomena provides a new means by which to reinterpret the representations used by space syntax theory.

In many ways the visibility accessibly problem is present in a building. Take for example the concept of an open plan office with many half-height cubicals. When arranged in the correct pattern we can observe the phenomena of a cube farm. Here the standing landscape/isovist gives complete visible access to the space but the physical blockage of the half height partitions gives rise to a denial of direct accessibly. The space is both trivial (single open space) and complex - requiring the planning a of a complex path though a labyrinth of partitions. Another example is that of a chest height hedge maze, here the way is playfully if deliberately blocked. This kind of maze is much simpler than that of a full height hedge maze as both orientation and global overview are constantly available. Neither are these situations confined to the building scale, at the smaller urban level one example is the use of pedestrian rails common in many city centres such as Oxford Circus or Piccadilly Circus to segregate pedestrian and vehicular traffic. With the barriers in place traversing the space necessitates planning a route around the visible barriers.

The question of this typology of space is ‘is this space simple or complex?’ From the point of view of a dog or child the space is clearly complex. From the point if view of a fully-grown adult the space is simpler but more complex than open space. If a space syntax analysis of the space was being completed the decision to which manner of depiction would be primarily regarded as an operational one. The decision would be made either intuitively or via experience and professionalism of the researcher. The space would then be mapped either as a single space or a complex labyrinth. In both cases the analysis this would be adequate but not totally representative. Intuition appeals that the space is neither fully complex nor a trivial single space but somewhere in between.

A second class of impedance in an office is the glass walled office. Again for more complex situations such as hospital theatres or reception spaces we are left with the operational question of how to map these phenomena axially. A second common type of glass barrier is that of the museum display cabinet. As with the glass cubical the space interrupts the free accessibility movement but affords some visual clue to the understanding of space. Related to both the half height cubical and the museum glass case is the circumstance of the sales area of a many department stores. In these contexts it is frequently possible to see to the far side of the store but the direct route is blocked by a complex array of display racks.

A second similar but not identical problem is that of the effect of signage in a building or an urban system like the Barbican. Here the sign indicates the presence and direction of a room or space or group of spaces (such as a department). The effect of the sign is to reduce the conceptual topological distance from one space to many others creating something similar to a hyperlink from one space to another. Currently there is no clear mechanism in space syntax to make allowance for the presence of signage in a complex building. The axial map is typically just a literal interpretation of the geometric space turning the space into a graph (network) representation, there is no leeway or facility for judgement to alter the description to permit signage to be taken strongly into account. Unlike a map a system of building signs are far from universal and arbitrary. Signs point from one location and link to one location. The signs are deliberate and will tend to eliminate redundant information. For example you may see a sign indicating the direction to a toilet but are unlikely to find one indicating the direction of the air-conditioning plant. A map on the other hand tends to be more fully representative. A map can also be used in a bidirectional linked way for example you may regularly find a sign leading to the toilets but not have one saying ‘this way back to the restaurant’. A map can be used in both directions of travel. While the existence of maps may be interpreted as a unbiased alteration of movement within a building the use of signs clearly is specific and deliberately biased to more segregated locations.

Crucial to the integration of the use of signage into space syntax is the interpretation of the effect of a sign has on distance. Take for example standing in the Barbican or in many hospitals. One might ask directions to a specific ward/space and be told ‘go down here turn left then follow the yellow line’. For space syntax the concept of a change of direction being synonymous with a step change in depth is common but following ‘the yellow line’ might involve several changes of direction which would no longer be need to be considered. In effect the existence of the yellow line conceptually ‘straightens’ the route but by a degree which is undetermined.

These and other similar phenomena can be reduced down to a consideration of the visibility and accessibility of space. Given that there are a number of phenomena which appear to reduce the topological depth from one space to another is there a single representation which can represent the problems presented? Pervious work such as Doxa(2001) has focused on an isovist Visibility

Graph approach, this paper contents that an axial approach which could be extended to the convex or the isovist representations of space can be a more elegant solution.

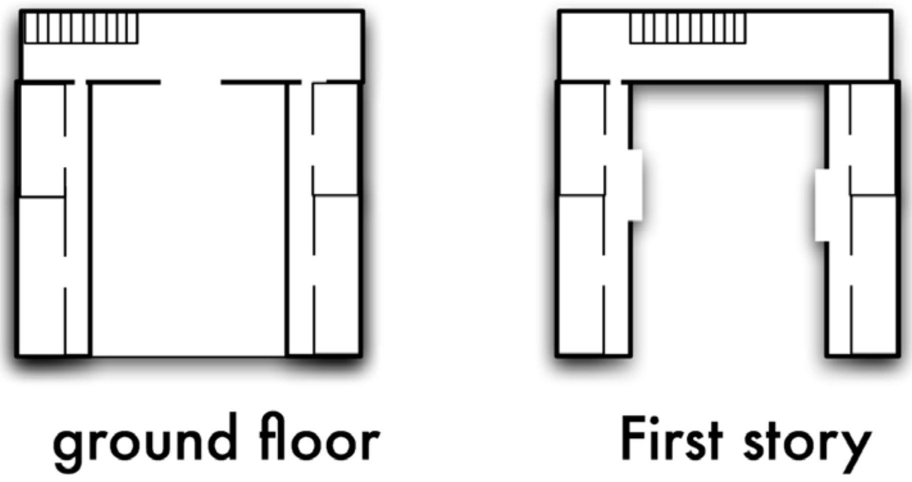

Figure 1
a simple court yard arragement with windows on the second story looking down on to the central space.

We can begin by looking at a simple hypothetical building. The space exists with a court yard looked down upon by a gallery from either side of the first story space. When one arrives it is possible both to see up and observe movement on the first story. From the point of view of the upper floors they are poorly constituted. From the ground it is clearly obvious that it is possible to find some currently hidden route up to the first story. It is also possible to interpret the space as open for communication. The visitor on the ground is potentially free to converse with others at the first story. The ablity to potentially be observed and interact with others is a component of a social space and yet in representational terms the two spaces have a large accessibility distance between them.

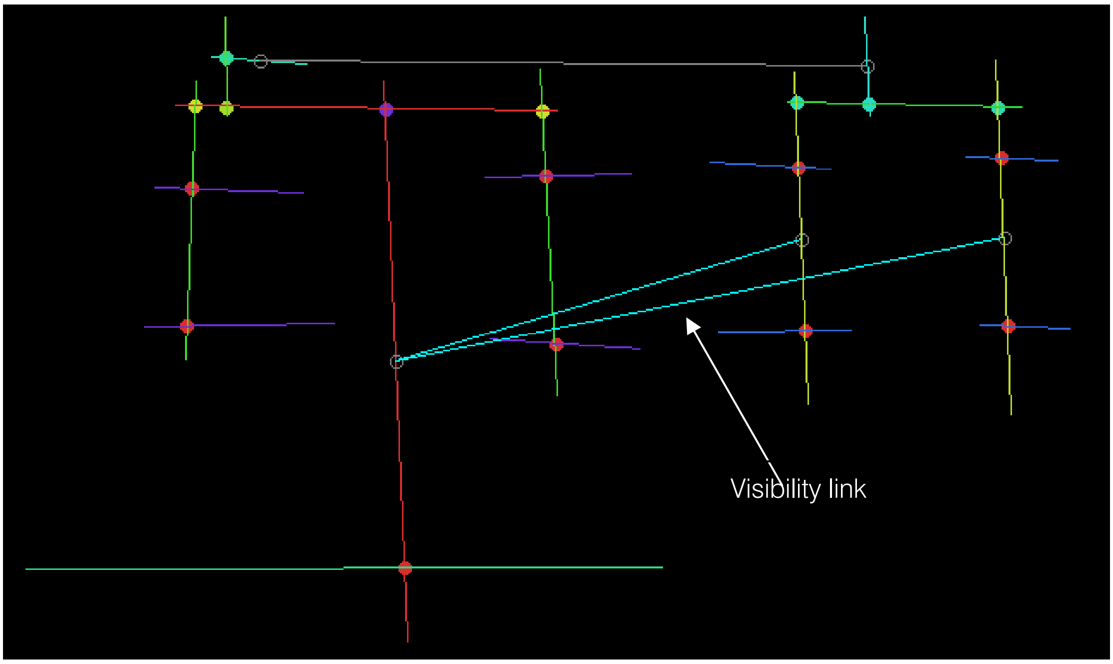

Figure 2
map of total depth of the axial map of the above building showing the courtyard as the most integrated space.

Figure 2 introduces a basic axial floor plan of an simple notional building with an entrance at the bottom of leading into a court yard. A stair case that is not directly visible from the entrance space, leading off the back of the court yard space leading up to the second story space. In figure 1 two extra non axial line links are introduced in cyan. These diagonal lines indicate the visible linkage between upper and lower spaces.

Traditional space syntax could take one of two methods to this problem. Firstly it can assume that the effect of the inter-visibility is small on the over all movement economy of the building. In this manner the accessibility axial map can be used. During the initial phases of the creation of space syntax this would be a viable mechanism. Yet given the number of architects who have designed spaces where you can see but not access directly it would be counter intuitive to dismiss this design work out of hand. Should we then model 'visibly' space ? This would mean effectively making each space that was visible also accessible; clearly this stands against intuition as well.

The proposal

The proposal of this note is that the traditional representation of space syntax can be extended in these situations. The core representation in space syntax is that for the graph or network. Mathematically the graph is represented by a set of nodes and a set of edges between nodes.

$$G = (N,E)$$

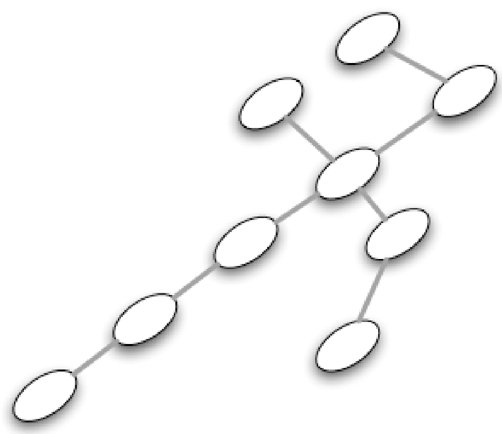

Figure 3
graph representation of a building

It is the proposal of this note that a more suitable representation is that of the layer-graph. A meta graph can be considered as a set of nodes and a set of sets of edges.

$$M = (N , \{ E1, E2, E3\ldots \})$$

The layer-graph can be considered to be a graph formed of layers. That is, nodes exist on each layer but the edges may differ from layer layer. A path can be formed through the edges in a layer but paths cannot be constructed from edges in more than one layer. As is common in space syntax edges are typically two way and edges may or may not be weighted. In this paper edges are not weighted.

For the case of the visibility/accessibility problem there are two edge sets the edge set of the visible (EV) and the edge set of accessible (EA). Note that the accessible edge set EA is the one we are typically familiar with in Space syntax. Not also that EA is also typcially a subset of EV and that EV is a superset of EA. That is we can always see everywhere we can directly access. This case might not be true in very rare circumstances such as the case of a fire where smoke has filled part of the building. In these situations we might be able to access a space (pass through it) but not see through it. In these exceptional circumstances EA would no longer be s complete subset of EV. It would be an interesting aspect of future research to explore these kinds of conditions. This is how ever a digression.

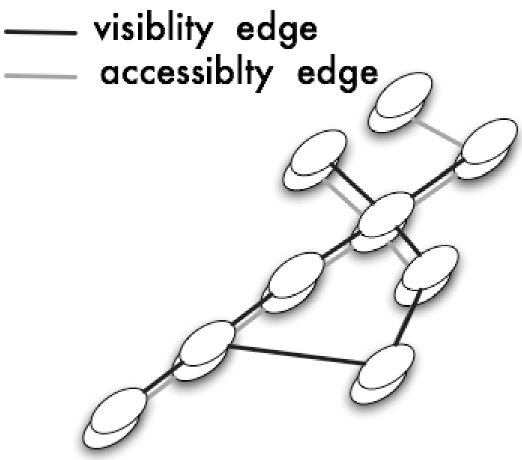

Figure 4
layer-graph with two 'layers'(edge sets)

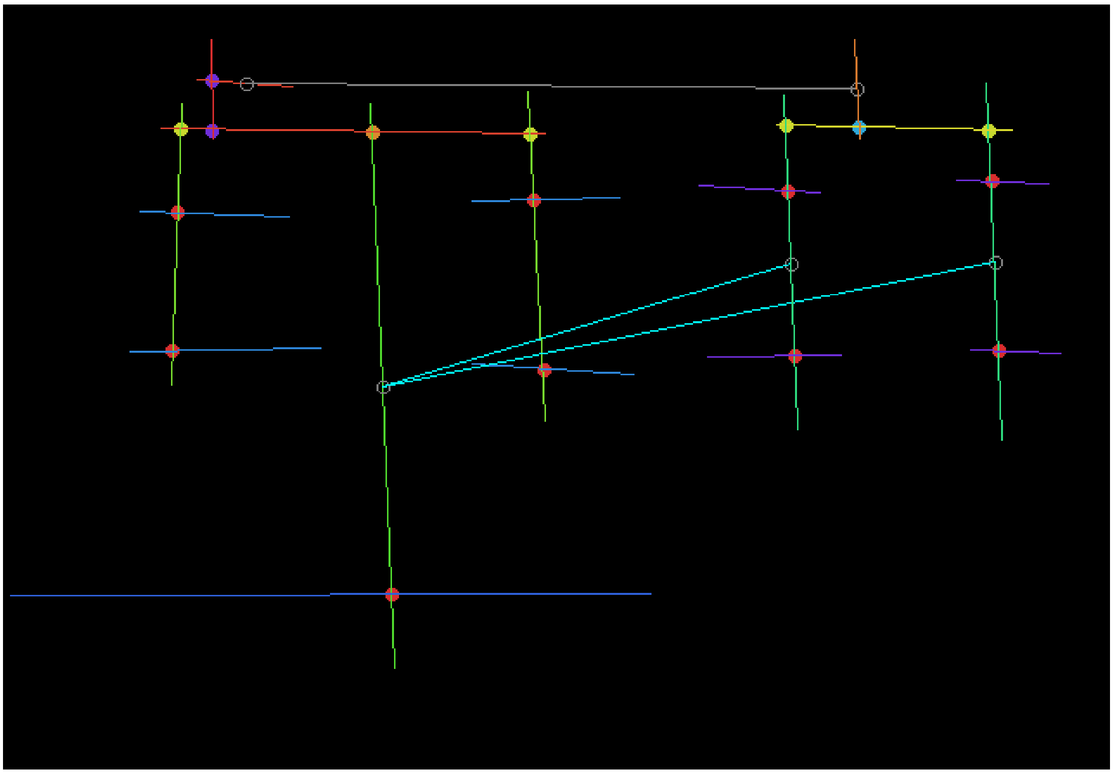

Figure 5
Visibility is accessibility depth

The diagram above shows an axial map representation of a court yard with a second story (to the left) forming an atrium around the lower floors. Along the top is a 'superlink' representation for the staircase between the ground and first floor. We can also identify two cyan links representing the visibility links between the ground entrance space and the upper level passage. All calculations where performed using Webmap@home (Dalton 2005) version 0.91.1.

The central observation of the layer-graph representation is that we can consider two graphs/networks. Firstly the accessibility graph (N,EA) must define the lower bound of the integration possibilities. Clearly it is unreasonable to assume that the integration of the upper floor will decrease if the visible. We can naturally expect that if the upper floor is directly visible then we can expect the degree of segregation to lower and at worst stay the same but not increase. The second observation is that the visibility graph where the treated as the accessibility graph, that is one could imagine an visitor could magically float up along the axis of visibility to the upper floor then the upper floor could be no less segregated.

Given the two observations above we can then come to the conclusion that the degree of segregation of the upper floor will be at worst no smaller the accessibility graph case and no better than the visibility graph case. Crucially to the hypothesis, we must conclude that the true degree of segregation of the upper floor given the status of its visibility must lie somewhere between the upper and lower limits.

Rewriting this in syntactical terms, if we consider the depth from the central lower atrium space to one of the upper levels. The depth to the upper level space will lie between the shortest geodetic depth (9 steps in the accessibility this example) and the shortest geodetic depth (3 in the visibility example). We might conclude that the simplest mechanism to measure the reduction in segregation is to interpolate the depth between the first and second cases. The simplest means to do this is to use a formula

$$Dhg(I,j) = Dea(I,j) * b + Dev * (1-b)$$

Where b (beta) is a constant factor between 1 and 0. Dhg is the meta graph geodetic distance between node I and node J and Dea is the shortest geodetic distance for the accessibility layer/graph and Dev is the matching distance for the visibility layer. In the above example given a beta factor of 0.5 we would find that the layer-graph depth is ((9*0.5)+ (6*0.5)) = 7.5. Clearly this can be used for non negatively weighted graphs and can be generalised if nessasry up to an arbitrary number of layers/edge sets.

Given the definition of layer-graph geodetic distance we can then build the familiar J graph representation (the all shortest routes to node I) and from this compute total and average depth in the familiar manner.

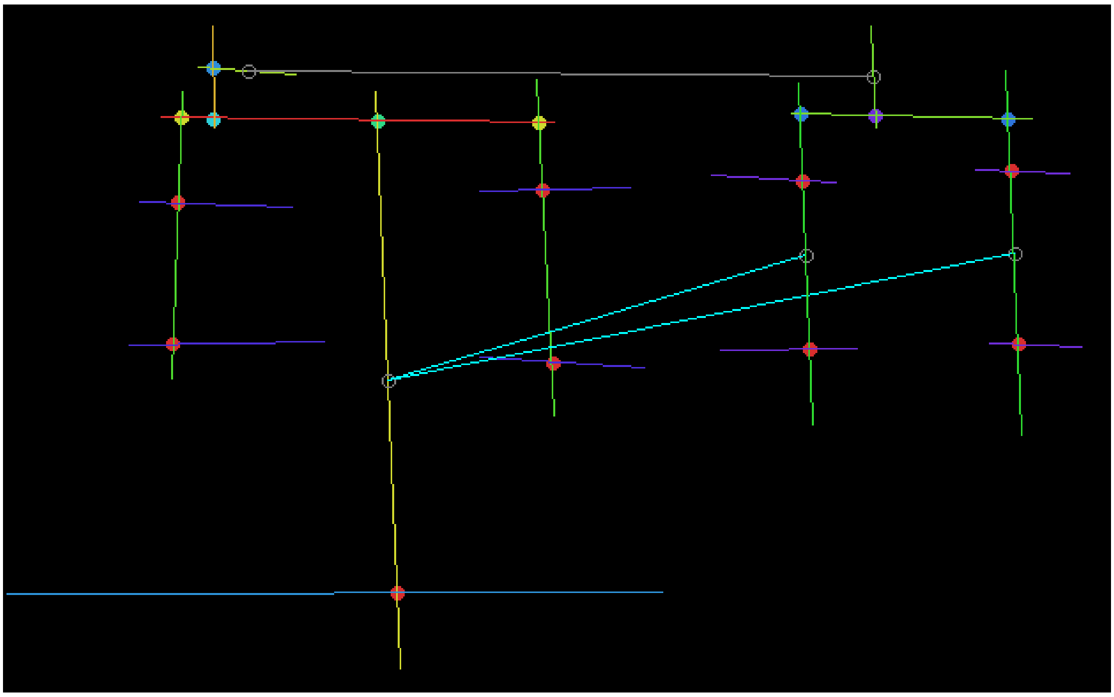

Figure 6
merged version beta=0.5

If we process the presented axial map in the above manner we find that total depth values for the upper floors becomes lower as expected. That is the presence of the visibility link reduce the degree of segregation of the upper level. The beta value of 0.5 is just a sample to demonstrate the influence of the visibility link of the integration patterns observed.

Setting the Beta value

The value of beta now becomes the clear factor necessary to understand the impact of visibility on the building. Given the current simple definition it might be possible to derive a value for beta by experimental means. Simply by experimenting over the range of beta values we can explore what beta factor might best improve the correlation with observed movement. A more detailed experiment would be to introduce a temporary visibility blockage to the space and then examine the long term effect on movement rates of new visitors to the space.

One final observation must be made is when beta =1.0 this is equivalent to the visibility-is-accessibility map and when beta = 0.0 this is identical to the accessibility only map (i.e total depth).

Extensions

Given the layer-graph mechanism it might be fruitful to explore the utility of this representation to other problems. Regard the above the figure again and this time image that the axial graph represents a non-atrium space. If the links now represented two signs indicating that the above spaces are present and the direction of travel. Again the core hypothesis that the existence of a sign cannot make the targeted location any further than the accessibility distance and no closer than a single change of direction. Observe also that in this case the sign-as-link is one way that is a sign can indicate the presence of a destination but once that destination is reached it cannot be used to return to the origin. It was as if the building was artfully constructed from many oneway mirrors. The layer-graph as description of a buildings signage could also be used to form simple experiments. If pedestrian foot fall via gate counts within a building could be observed both with and without signage then it might be possible to estimate the beta value necessary to make the observations agree with the representation and so calibrate to some degree. Clearly it is simpler to alter signage to some extent than to modify the visibility of a building and so form a viable empirical test of the layer-graph representation.

Layer-graph and intelligibility

It has become most apparent that the effect of signage is to lower the segregation (total depth or raise the integration measure) value. The other aspect we might expect of a layer-graph via signage is that it might raise the intelligibility of a building. This hypothesis would be suitable for testing via the basic observation that the intelligibility of the layer-graph of a well signed building should be reasonably expected to be higher than that of the pure accessibility graph. This leads to one theoretical problem that is that of how to measure connectivity in the context of a layer-graph. Each node has two or more edge sets leading from it so the degree becomes an ordered list of degrees of each of the edge set. That is for each layer there is a different connectivity/degree. It would be reasonable to assume that one definition of connectivity in the context of a hyper graph is to apply the beta factor to the degree/connectivity. So for a node N with Edge set E1 and E2

$$K(N) = k(N,E1) * b + (1-b) * k(N,E2)$$

Where K(N) is the degree/connectivity of node and k(N,E) is the degree of edge set E for node N. Given K and Total depth an non comparative approximation of intelligibility can be created.

Conclusions

This paper has introduced the concept of layer-graph and shown how it can be used in space syntax to represent a wide range of conditions including the visibility/accessibly problem and potentially signage in buildings. This layer-graph approach does appear to be a generalisation of the space syntax concept. For example when the general case of accessibility matching visibility then the layer-graph simplifies down to the simpler graph approach typical of the space syntax literature. While space has not permitted the introduction of angle or weighting the concept of layer-graph is not antithetical to the approach. It is evident that the layer-graph approach can be used to represent a number of differing problematic cases found in real world buildings and urban environments. As such it seems reasonable to warrant further research and testing in this area.

References

Dalton, S. N. 2005. WebmapAtHome. London.

Doxa,M. 2001. Morphologies of Co-presence in Interior Public Space in Places of Performance The Royal Festival Hall and the Royal National Theatre of London. *Proceedings . 3rd International Space Syntax Symposium Atlanta 2001*.

Hillier, B. 1996. *Space is the Machine*. London: Cambridge University Press.

Hillier, B. and J. Hanson (1984). The Social Logic of Space. Cambridge, Cambridge University Press.

Hillier, B., A. Penn, et al. 1993. Natural movement: or, configuration and attraction in urban pedestrian movement. *Environment and Planning B: Planning and Design* 19.

Hillier. B 1999. The hidden geometry of deformed grids: or why space syntax works, when it looks as though it shouldn't. *Environment and Planning B: Planning and Design* 26(2): 169-191.

Parvin, A., Y. A. Min and J. Beisi. 2008. Effect of visibility on multilevel movement: a study of the high-density compact built environment in Hong Kong. *Urban Design International*,Vol 13,3,pages 169--181