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IN THE INTELLIGIBILITY MAZE OF SPACE SYNTAX:

A space syntax analysis of toy models, mazes and labyrinths

082

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Abstract

Using axial map representation, space syntax research has found that spatial configuration analysis correlates with patterns of the movement flows. "Intelligibility" a second order measure, defined as the correlation between connectivity and global integration has been proposed as a necessary condition for such correlates to occur i.e. when such condition is not fulfilled, correlates are not or less expected.

In this paper we investigate the spatial configuration analysis of Toy Models that have been used to demonstrate issues of "intelligibility" along the spatial layout of labyrinths, mazes, and strict grid: we find inconsistencies. We show that these inconsistencies may arise because such Toy Models, Labyrinths and Mazes depart from the line distributions which display universal features independent of city size found in urban real world city or part of city.

The main conclusions of this paper is that on one hand, the measure of intelligibility which space syntax research claims is crucial for correlates to occur is inconsistent with particular spatial systems such as Toy Models. On the other hand, it seems that distribution of axial line length may explain these inconsistencies. It is suggested that Toy Models are misleading to discuss "intelligibility" and that checking line length distribution, a first order measure, might give some clues to urban designer as to whether a spatial system might be "intelligible" or not in dense urban areas. Further research is needed in relation to configurational analysis using segment representation that give better correlates but have not been characterised in relation to "intelligibility".

Keywords: *intelligibility, inconsistency, maze, spatial cognition*

Theme: *Spatial Cognition and Behaviours*

INTRODUCTION: Intelligibility in space syntax

Space syntax analysis which represents and quantifies aspects of spatial pattern with axial map has found that spatial configuration correlates with observed movement flow levels by both pedestrians (e.g., Hillier, Burdett, Peponis, & Penn, 1987; Hillier, Hanson, Peponis, Hudson, & Burdett, 1983; Hillier, Penn, Hanson, Grajewski, & Xu, 1993; Peponis, Hadjinikolaou, Livieratos, & Fatouros, 1989; Read, 1999) and drivers (Penn, Hillier, Banister, & Xu, 1998a, 1998b). However, it was observed that spatial configuration sometimes fails to predict pedestrian movement flows in dense multi-level urban areas (Chang & Penn,1998; Parvin, Min, & Beisi, 1998). Chang & Penn (1998) investigated pedestrian movement behaviour in two multi-level urban complexes, a conventional space syntax analysis found no correlates or almost. Chang and Penn attributed these results to the poor correlation of local and global measures, the lack of "intelligibility". Later it was proposed that the degree of "intelligibility" affects the predictability of pedestrian spatial distribution (Hillier, 1999, Penn 2003) making "intelligibility" an almost necessary conditions for such correlates.

The concept of intelligibility was firstly introduced by Hillier et al (1987). "Intelligibility" is quantified as a second order measure. It is defined as the degree of correlation between connectivity and global integration values of the axial lines in spatial configuration analysis. Hillier hypothesized that the high correlation between connectivity and global integration ensures that the spatial configuration is understandable and predictable for the pedestrian or vehicular movement. He explained this property as follows:

> "*The property of 'intelligibility' in a deformed grid 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*."(Hillier 1996, 94)

The "property" of intelligibility conjures up aspects of spatial cognition that pertain to navigation, way finding, motion and spatial reference, memory, spatial relations and spatial inferences.

Although most of the current studies (Hillier et al 1993, Chang & Penn 1998, Kim 1999, Conroy 2001, Hillier 2002) proposed that intelligibility is a property that links to space cognition and spatial use pattern, and ensures the predictability of a system, there are differences in its definition:

- Read(1999) investigated 36 areas in five Dutch cities. He proposed that high mean connectivity produces high intelligibility, and the correlation between predictability of public space occupation rates and the space syntax measure of intelligibility breaks down in conditions where mean connectivity becomes low.

- Dalton(2011) dealing with the problem of neighbourhood definition and normalisation of intelligibility and synergy, suggested that the size of the system has some effect on the navigational task, and that intelligibility and synergy will both decrease as the size of the system grows. Yet, it is recognised that it is possible to make a small system difficult to navigate, such as mazes.

Dense urban environment, such as sub centres in metropolitan area are our prime interest. As Asian metropolitan become larger, the size, configuration and importance of city part design increase, in particular sub centre. Metropolitan sub-centre planned around mass public transport are larger and more convex than linear sub-centre as found in, for example, in Greater London Authority area (Chiaradia et al. 2012). It becomes much more important for urban designer to achieve effective and efficient understanding of the design issues involved in intelligible spatial design. Investigating the details of "intelligibility" which is a second order measure may help to discover first order measures that are salient and relevant to urban designer.

The paper explore broadly the following interrelated questions:

- Are toy model good representation of urban area? Under what condition can they be used as tool for conceptual exploration or virtual environment for virtual navigation empirical studies? Re-stated are Toy Models a good representative sample of an urban area? How could "representative" be determined?
- What should we use to measure intelligibility VGA or axial line or something else?
- What are the spatial design profile of intelligible area, more or less intelligible enabling directed divergence and more choice, and unintelligible area?
- What is the specification of change in intelligibility in relationship to correlates?

The paper is organised as follow, in the first part we re-analyse spatial system used in the space syntax literature to demonstrate issues of measuring "intelligibility". The findings identify issues of incommensurability and inconsistencies. The second part investigate particular type of space configuration to test to the limit the measure of intelligibility by analysing the configuration of Labyrinths, Mazes and strict regular grids, again inconsistencies are found. In the last part we investigate first order measure such as axial line length and connectivity to track down and explain the inconsistencies found so far. We conclude with a discussion of the findings and further research directions.

1. Inconsistency of Intelligibility in space syntax Toy models

In the space syntax literature a set of notional spatial models have been used to demonstrate some configurational analysis issues (Hillier 1996, Hillier 1999). We call these spatial models "Toy Models" to denote that they might be useful device yet that they are not representative of real world situation. In the following section we focus on two set of Toy Models that have been repetitively used (Hillier 1996, Hillier & Iida 2005, Raford& Hillier 2005, Hillier 2012a, 2012b, 2012c) to argue the importance of intelligibility which has become a prominent and ubiquitous feature in the space syntax literature. While intelligibility definition arises with axial map, a linear representation of space, it is Visual Graph Analysis (VGA) that is used, a point based analysis. We show that the two analyses yield very inconsistent results and as such are incommensurable.

1.1 VGA and AGAM intelligibility in space syntax Toy models

In *Space is the Machine* (Hillier 1996), two spatial layout are used as examples of intelligible and unintelligible environments (Figure 1-a & b). Small changes of the layout have a significant effect on the VGA intelligibility, the r2 between the VGA connectivity and VGA visual integration of point is 0.835 in the initial layout and 0.148 in the altered layout. The decrease in intelligibility reach -82%. The initial spatial layout is made of variable urban block shapes and sizes organized in a deformed wheel pattern, with a spatial focus on the east. A Street running East-West crosses the whole spatial system and the spatial focus. The changes fragment this pattern and create various large spaces around what was the focus. We re-analyse this layout using

Algorithmic Generated Axial Map (AGAM) using space syntax official Depthmap software to implement AGAM (Turner, Penn, and Hillier, 2005).

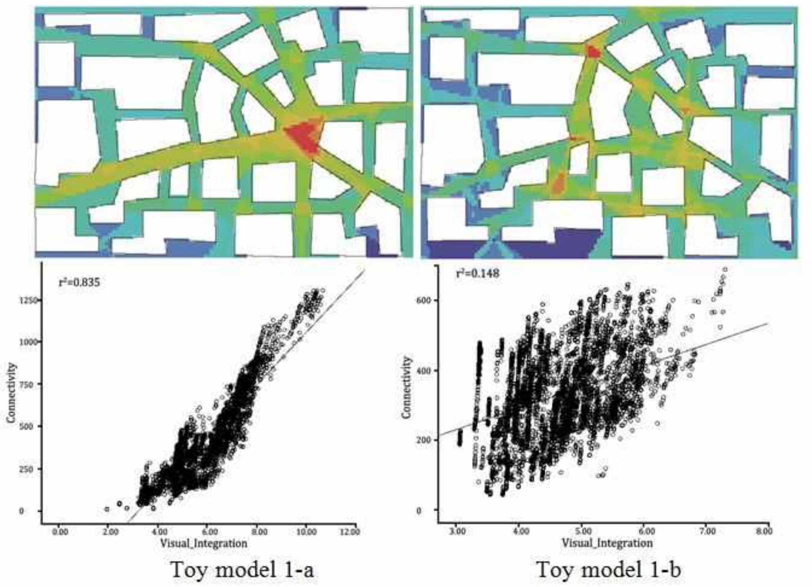


Figure 1: VGA Intelligibility and unintelligibility layouts (Hillier, 1996).

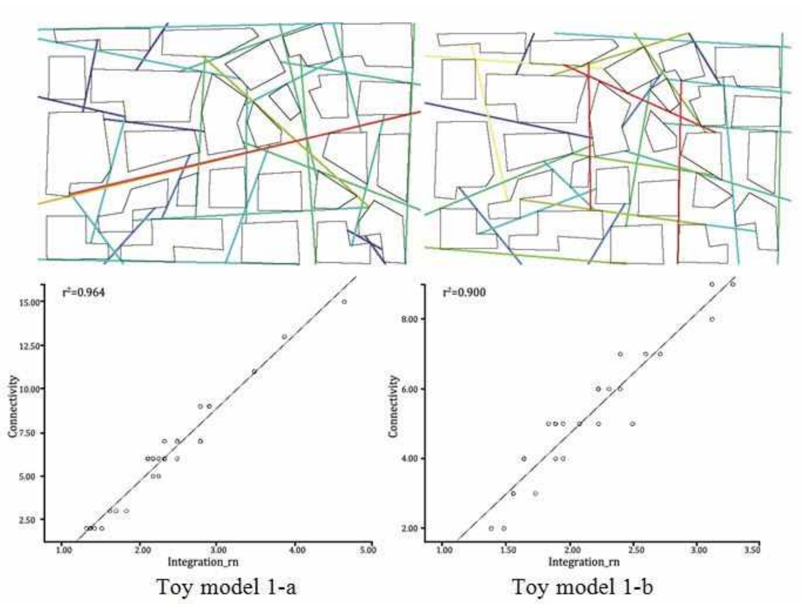
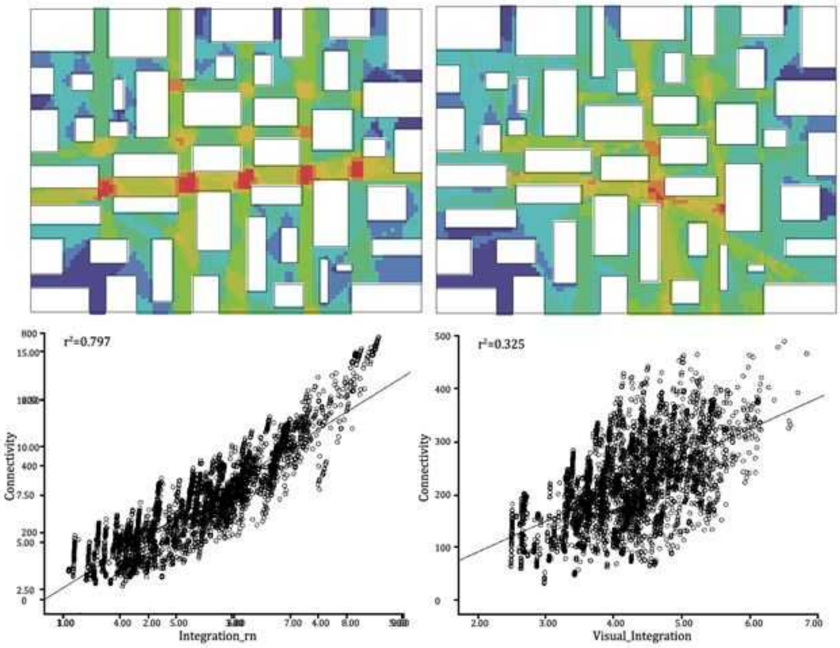


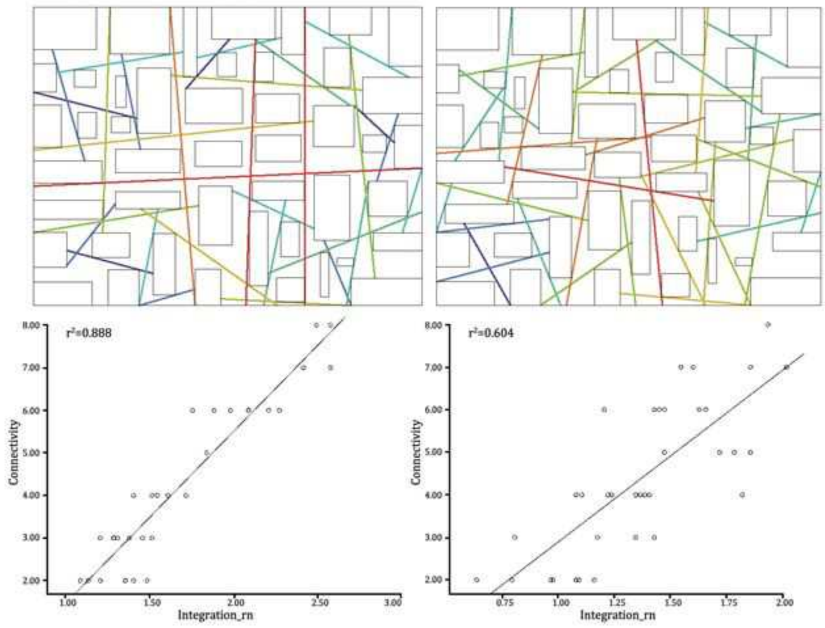
Figure 2: AGAM intelligibility and unintelligibility analysis.

As shown by Figure 2, intelligibility is very high for both of the initial and the changed layouts, r2 = 0.964 and 0.900 respectively, a decrease of only 7% i.e. negligible given the high level of intelligibility.

We also re-analyse the other pair of layouts used in Hillier& Iida (2005) and Hillier (2012b, 2012c). The spatial system has a similar number of VGA tiles in Toy Model_2a (4014), 2b (3989) than 1a (4446) and 1b (5216). The layout is made of rectangular urban blocks organised on a deformed grid. East-West and North South streets traverse the spatial system. Changes in the layout fragment the continuity of these global streets. There is no spatial focus. Changes in the layout have major effect on VGA intelligibility which change from r2 = 0.797 to 0.325, a significant decrease of 60% (Figure 3_a).



(a) VGA intelligibility



(b) AGAM intelligibility

Toy model 2-a Toy Model 2-b

Figure 3: VGA, AGAM intelligibility and unintelligibility analysis (Hillier & Iida 2005).

As above we use AGAM, and found that intelligibility changes from r2 = 0.888 to 0.604 (Figure 3_b), a significant decrease of 32% yet half the size of the corresponding VGA intelligibility decrease.

To summarize: the two VGA spatial systems have similar VGA tile number (Table 1). For Toy models 1a and 1b, VGA intelligibility decreases from 0.835 to 0.148 (-82%) while for AGAM it decreases from 0.964 to 0.900 (-7%), for Toy Models 2a and 2b, VGA intelligibility decreases from 0.797 to 0.325 (-60%) while for AGAM it decreases from 0.888 to 0.604 (-32%).

The three papers (Hillier Iida, 2005, Hillier 2012b, 2012c) make reference to the behavior of forward looking agent. Low "intelligibility" is given as explaining the difference of the spatial distribution of agents. Reference is also made to actual subjects asked to navigate a 3D immersive worlds (Conroy Dalton, 2001, 82-86) as in 1a and 1b. The navigation tasks were clearly divided into two sub tasks "to reach a monument" located on the focus space and to come back to the starting point. The findings are expressing much more subtle difference between the two layouts than the overstatement: *"The subject found the modified layout (unintelligible layout) labyrinthine (maze like is the appropriate term) and many wandered all over the system trying to perform the same way finding task."* (Hillier 2012, 39).

However for the "unintelligible" layout, it is stated that "*if only the routes as far as the way finding goal (finding the monument) are analyzed, it is clear that a higher proportion of the routes are similar*." (Conroy Dalton 2001, p.102-104). The greatest divergences appear for both the intelligible and the unintelligible layout once the first way finding task has been completed: i.e. in both layout, more divergence occur for the task of walking back to the origin.

Intelligible layout and unintelligible layout are very similar in term of intelligibility, convergence level of paths, up to the monument. In that sense AGAM intelligibility levels is probably a better representation of this empirical experiment than VGA intelligibility. As urban design for crowded Asian city we may also want to consider avoiding over concentration of pedestrian and create environment that not just only concentrate flow, risking overcrowding and level of service decrease, but allow for some low level divergence in path selection, alternative paths or enabling easy urban exploration. It seems to us that Toy Model 1b is a perfectly legitimate design offering "design controlled" low level path divergences that seems well captured by AGAM intelligibility.

Regarding the second part of the way finding task, higher divergence occur for both intelligible and unintelligible layout. It seems that there is a strong asymmetry between the first task and the second task. This might be due to the experimental settings: when starting the subjects are oriented toward the monument. Once the subjects have reached the monument they need to have a sense of the direction of where they came from which is not explicitly given as when they have started. This asymmetry might be partly an artifact of the experimental settings. Some subject may be better at dead reckoning of the initial location than other which might be enhanced or inhibited by the layout. Such an asymmetry between forth and back and their divergence is also found in very simple and intelligible layout (Conroy, 2003, 127-129). The empirical study as it currently stands does not allow for strong inference: it might be the layout, it might be the subjects, and it might be the experimental settings. Probably a bit of all.

The following comments are in order:

1. Before discussing the results of intelligibility analysis using Toy Models, it is to be noted that it is surprising to see the repetitive use of VGA to demonstrate issues in urban configuration, an analysis which is usually not often used for urban analysis. How do we know that Toy model are representative of urban areas?

2. Following 1, it is even more surprising that VGA is used as very few publication use VGA to correlate with pedestrian movement in urban setting. For example Turner (2003) shows that VGA is less robust than axial map analysis. Although Desyllas &

Duxbury (2001) have shown that this might be due to spatial mapping issues: high vs. low resolution spatial mapping.

3. Not acknowledged, it is known by the main author propounding intelligibility that VGA is sensitive to multiple area unit problems, as such confounding configurational variables with area size variable (Hillier, 1996, 105).

4. The AGAM re-analysis shows that VGA and AGAM intelligibility analysis are inconsistent and as such incommensurable. While VGA show large variations in intelligibility, AGAM show slight variations (Toy Model 1) or show variations that are very different in magnitude (Toy Model 2). A limited empirical study seems to credit AGAM intelligibility as a better index of perceived intelligibility.

5. The Toy Models 1 and 2 are differentiable: a deformed wheel vs. a deformed grids yield very different sensitivity to layout changes. The space syntax literature is mute as to whether movement correlates would vary proportionally or not i.e. what is the specification of the relationship between changes in intelligibility and correlates: is it linear, polynomial, log-log, etc. This would be of great interest to urban designer.

1. 2 Scaling study of Toy models

To explore point 3 we undertake a scaling study. We scale up and down both pairs of layouts and VGA tile size to investigate VGA intelligibility and axial intelligibility stability, the results are presented in Table 1. We find that the VGA intelligibility changes irregularly while the scale of models changes, while AGAM intelligibility does not change at all. The latter is seemingly reassuring, yet AGAM stability is to be questioned in relationship to the definition of Intelligibility: from one space how far can one see how many other spaces are connected if the spatial scale become very large? Is decision making in route choice and path selection not only informed by cognitive distance but also affected by perceived Euclidean distance, captured in the Euclidean radius? So how is scaling affecting VGA intelligibility?

Measures	1/10times	1/5 times	1/2 times	1 time	2 times	5 times	10 times
1a_VGA_Intelligibility	0.858	0.828	0.852	0.835	0.836	0.832	0.834
1a_VGA_Tile number	4457	4588	4419	4446	4456	4587	4586
1a_AGAM_Intelligibility	0.949	0.949	0.949	0.949	0.949	0.949	0.949
1a_AGAM_Axial number	30	30	30	30	30	30	30
1b_VGA_Intelligibility	0.202	0.205	0.294	0.148	0.115	0.222	0.186
1b_VGA_Tile number	5193	3346	5260	5216	3423	5205	5210
1b_AGAM_Intelligibility	0.900	0.900	0.900	0.900	0.900	0.900	0.900
1b_AGAM_Axial number	27	27	27	27	27	27	27
2a_VGA_Intelligibility	0.812	0.812	0.806	0.797	0.815	0.805	0.792
2a_VGA_Tile number	4012	3978	3965	4014	3996	3949	3968
2a_AGAM_Intelligibility	0.888	0.888	0.888	0.888	0.888	0.888	0.888
2a_AGAM_Axial number	31	31	31	31	31	31	31
2b_VGA_Intelligibility	0.311	0.289	0.307	0.325	0.274	0.320	0.275
2b_VGA_Tile number	4024	6992	3976	3989	3999	3979	3999
2b_AGAM_Intelligibility	0.604	0.604	0.604	0.604	0.604	0.604	0.604
2b_AGAM_Axial number	35	35	35	35	35	35	35

Table 1. Intelligibility in scaled toy model

The irregularly changes of VGA intelligibility shows that the measure of intelligibility is variables under scale changes while VGA tile number remain relatively constant. This sensitivity would probably increase if we were not to scale the VGA tiling. This means that the use of VGA with Toy Models require cautious use to avoid inconsistencies that would affect intelligibility measure. AGAM analysis with Euclidean radius would prevent the issues.

1.3 Frame study of Toy models

Three different frames for the Toy Model_1 were found in the literature (Hillier 1996, Conroy-Dalton 2001, Hillier 2012a, 2012b, 2012c), using VGA we define two different frames for Hillier1996 as frame 0, and frame 2, and the frame for Conroy 2001 and Hillier 2012a,b,c as frame 4 (Figure 4).We also insert two more frames: Frame 1 which is between Frame 0 and 2, and Frame 3 between 2 and 4. We investigate both VGA and AGAM intelligibility to edge definitions.

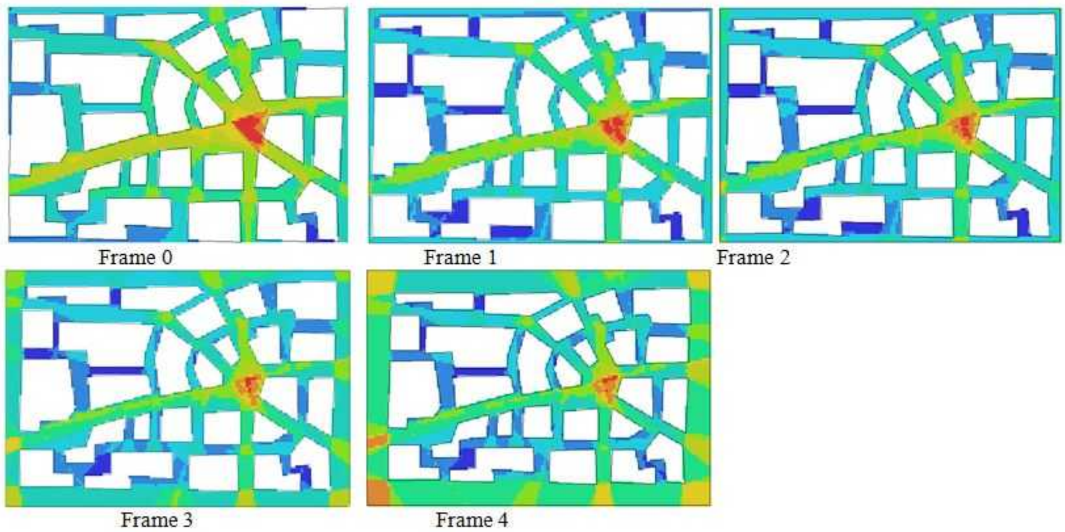
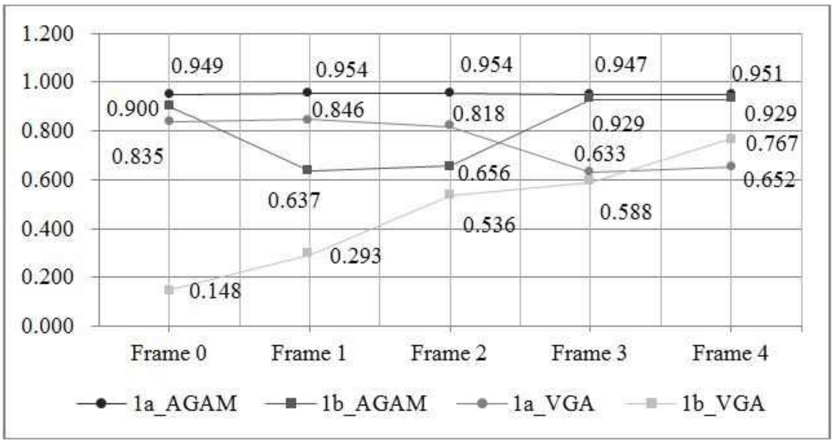


Figure 4. Five Different Frames (tile number: 4446,4668, 5084, 6495,7869)

The results shows that VGA intelligibility is very sensitive to the frame definition in toy model （Graph 1） in a rather inconsistent pattern. There is a trend that the VGA intelligibility decrease for the base case (Toy Model 1_a), from 0.835to 0.633 while tile number are increasing, and VGA Intelligibility increase for Toy Model 1_b, from 0.148 to 0.767 while tile number increase. We observe divergent pattern of VGA intelligibility with increase in tile number for different edge definitions. There is not a systematic decay of intelligibility with tile VGA tile number increase. However, AGAM Intelligibility is much more stable, we can see that it is not always congruent with VGA changes.



Graph 1: Intelligibility in frame definition study

We pursue the investigation of "intelligibility" by studying the configuration of Labyrinths, Mazes and regular grids as extreme limit test cases.

2. Intelligibility in Labyrinth and Mazes and regular grid

In *The Social Logic of Space* (1984, 45), Hillier and Hanson focused on the law of constructability of patterns in producing global order out of local rules:

> *"Methodologically there is a problem of morphology what can be constructed so as to be knowable - and a problem of knowability - how it is that descriptions can be known. Ultimately the crucial question will be how these two are related to each other, and even how far they can be regarded as the same thing".*

This theme is explored in more details in Hillier (2012). In this section what we set out to explore is what can be constructed so as to be knowable and yet how this description may remain unknowable, "unintelligible": labyrinth, mazes and regular grid are investigated. Profiling labyrinths, mazes spatial design configuration is of importance to urban designer, as it may help to equip designer with an understanding of such spaces and help them to be more spatially sophisticated.

In the first section 'Labyrinths', which are older, safer designs, offer no choices, reliably delivering the faithful walker to the centre every time as long as she continue ahead on the path. The second section, by contrast, deals with 'Mazes', designs in which you can get lost, where choices are offered to the walker and some paths may not lead to the goal; mazes are, by and large, a modern trend. The third section deals with regular grid which as labyrinths would in principle deliver the walker to wherever desired yet it is argued those regular grids are not intelligible when experienced.

2.1 Labyrinth

"***A labyrinth*** *is defined as a construction that leads from a starting point to a goal by a single path, with no branches or dead-ends.*", people will never get lost in a labyrinth because of its unicursal character. Using AGAM, Figure 5-a shows, this classical labyrinth from ancient Greek (2500BC) only has one simple way to go through or exit.

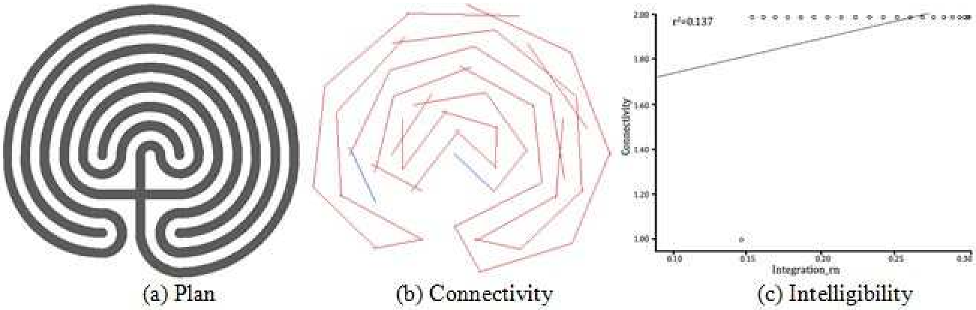


Figure 5: Ancient Greek Seven-coil Labyrinth

The space syntax analysis shows the layout has various values of global integration (from 0.146 to 0.300) and only two different values of connectivity, the connectivity of the first and the last axial are 1 (Figure 5-b), while the others are 2, thus the intelligibility is only 0.137 (Figure 5-c).

The spatial figure of the labyrinth offers very little as to what can be seen from any particular line, it does not have much connectivity either and yet, if trusted, it delivers the destination. Many real situations are labyrinths like e.g. underground station platform are alike labyrinth: to and from platform are easily reached by simply following the path. Yet a labyrinth is unlikely to be an urban layout, perhaps a winding path to reach a destination in the country side.

2.2 Mazes

"***A maze****, by contrast, is multicursal and calls for the traveller to make a series of decisions, which affects how quickly the goal is reached.*"

It is apparent that a maze is designed to make the task of navigation as difficult as possible, and yet a maze can be constructed from part that are easy to understand and can be easily assembled into a whole as a figure while the whole is unintelligible if not unknowable when experienced. According to the definition of intelligibility, the relationship between local and global measures in mazes should be low.

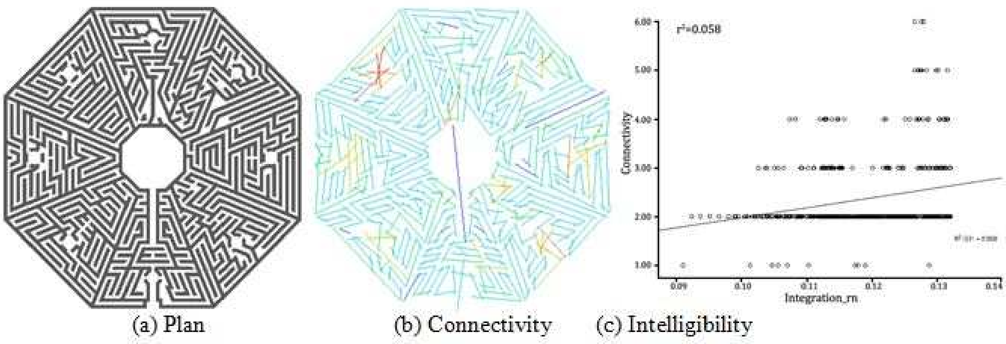
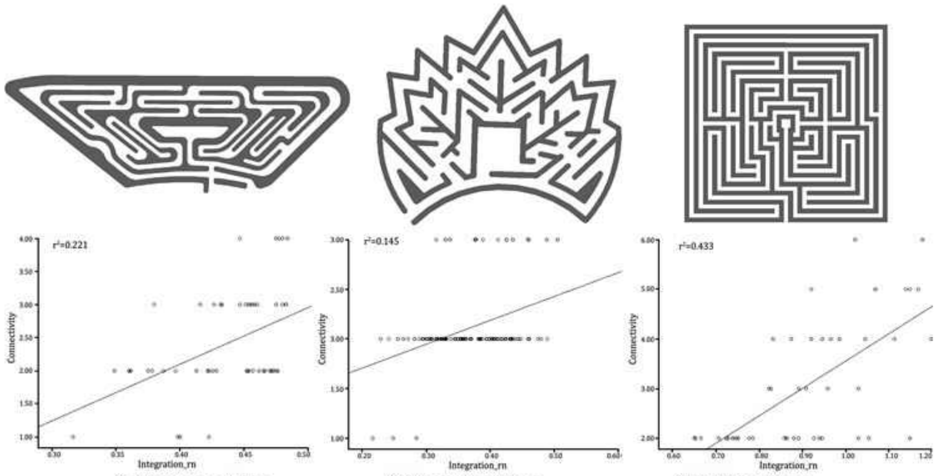


Figure 6: Ancient Chinese Maze

Figure 6 shows an ancient Chinese Stone Sentinel Maze, which is classical and difficult to navigate. The r2 correlation between connectivity and global integration is 0.058.

Three more mazes with different shape and size are investigated (Figure 7). The configurationally analysis measures of connectivity, integration and intelligibility are all to better know how unknowable spaces are characterised using configurational analysis. This is in order to see whether they can give clues for understanding the samples' spatial configuration.



(a) Hampton Maze (b)Chevening Maze (c)Dobbies Maze

Figure 7: Three Mazes in the United Kingdom.

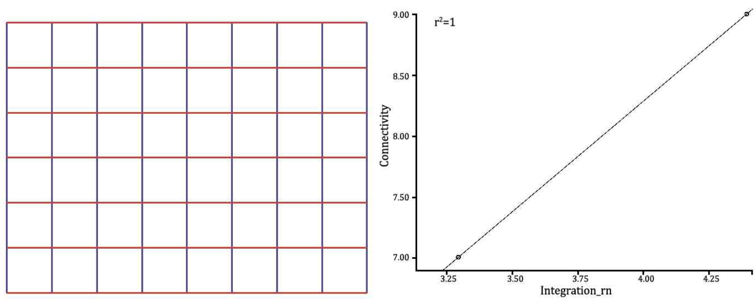
Labyrinth or Maze	Number of lines	Mean Connectivity	Mean Integration(Rn)	Axial Intelligibility r²
Seven-coil Labyrinth	43	1.953	0.231	0.137
Stone Sentinel Maze	478	2.347	0.118	0.058
Hampton Court Palace	55	2.400	0.435	0.221
Chevening House Maze	94	2.106	0.366	0.145
Dobbies Maze World-2	46	3.087	0.915	0.433

Table 2: Intelligibility in a sample of mazes.

Using the number of axial line as the index of size, the samples vary from 43 axial lines (Seven-coil Labyrinth) to 478 lines (Stone Sentinel Maze). As we can see from **오류! 참조 원본을 찾을 수 없습니다.**, the intelligibility of the Labyrinth is 0.137, while the intelligibility of the mazes varies from 0.058 (Stone Sentinel Maze) to 0.433 (Dobbies Maze World-2). According to the definition of intelligibility, it is difficult to conceive that a simple labyrinth can have such a low intelligibility value, and that a maze can have such a high intelligibility value.

2.3 Regular grids

Dalton (2011) has mentioned this over simplification problem of intelligibility. If we take a strict N by M grid of axial lines (where N ≠ M), N can be infinite then there are only two values for integration, and only two values for connectivity, so the intelligibility value will equal one.



(a) (b)

Figure 1: Integration and intelligibility in grids

For example let's take a strict 6 by 8 grid as example (Figure 8), it gives only two values for connectivity, 7 and 9, with the global integration of 3.29 and 4.39 respectively. Clearly there will be only 2 points in the scatter plot of intelligibility, the intelligibility value will be one (Figure 8-b) and will never change when the size of grid changes. If the grid is so regular we may able to navigate it without ever knowing that we are twice at the same place, as in such grid everywhere except the edges are the same. A numbering system would help to locate oneself, alternatively varying the block build up, creating landmark, will help to differentiate location and help navigation (Lynch, 1960).

3. Line length and Connectivity

In part 1 using Toy Models 1 we have shown that

- VGA "intelligibility" is incommensurable with AGAM "intelligibility" and that as such VGA "intelligibility" is probably unreliable.

- AGAM "intelligibility" varies differently according to the type of spatial configuration whether it is a radio-concentric layout or if it is more like a grid. From the existing literature we are not able to ascertain how these findings would proportionally reflect in pedestrian correlates variations or not. We conjecture that the relation is probably non-linear.

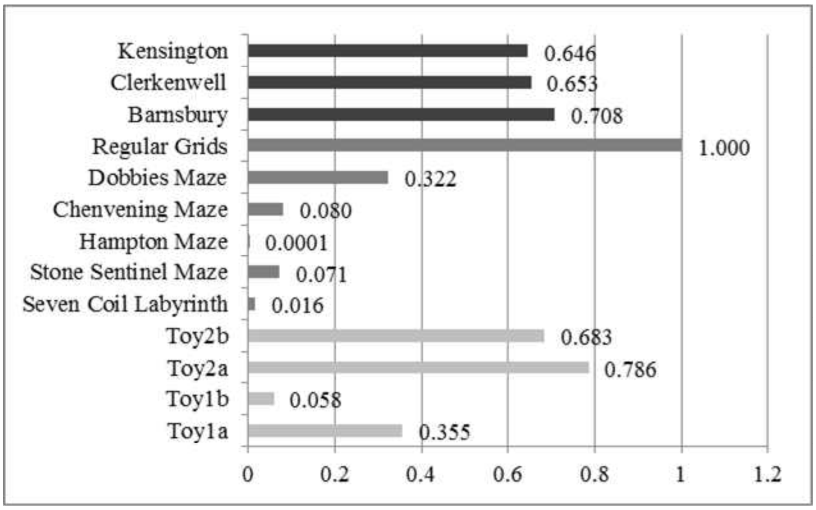
In part 2 using Labyrinths, Mazes and regular grid, which are not deformed grid per se; intelligibility as "*the degree to which what we can see from the spaces that make up the system - that is how many other spaces are connected to - is a good guide to what we cannot see, that is the integration of each space into the system as a whole*" may not be consistent with what we would expect of an index of intelligibility i.e. labyrinths which are easy to navigate appear to have lower "intelligibility" than maze. By contrast regular grids which have an intelligibility of 1 would not be very predictable if this is the only spatial layout information we would have.

In the following section we demonstrate that these problems may not arise in urban real world situation. To this end we first investigate line length distribution and connectivity and line length in the spatial map used so far.

3.1 Correlation between line length and connectivity

(Hillier, 1999) found that one of the most pervasive correlations in axial maps of cities is that between the length of lines and their connectivity. He proposed that in the towns where the process of growth has been organic, the degree of agreement between the length of lines and their connectivity is one of the foundations of order in the system.

In the same year, Read (1999) investigated 36 areas in five Dutch cities. He proposed that local integration and global integration will tend to become more alike when mean connectivity is high, thus automatically tending to produce high intelligibility and high correlation between predictability and intelligibility. We investigate the relationship of line length and connectivity for the above spatial systems and three urban areas used in Hillier and Iida 2005: Barnsbury, Clerkenwell, and Kensington. The results are shown in Graph 2.



Graph 1: Correlation of axial line length and connectivity

The correlation between the length of axial lines and their connectivity are tested in all of the above samples in order to see whether it is affected by line distribution. There are high correlation in all of the city areas and some of the Toy-models 2 (above 0.5), yet lower in Toy Model 1, while this correlation breaks down in the labyrinth and mazes (below 0.1). It is noticeable that:

1. The Toy Models which are grid like, deformed grids, have an overall correlation that is much higher than Toy Model 1 which has a spatial organisation that is radio-concentric.

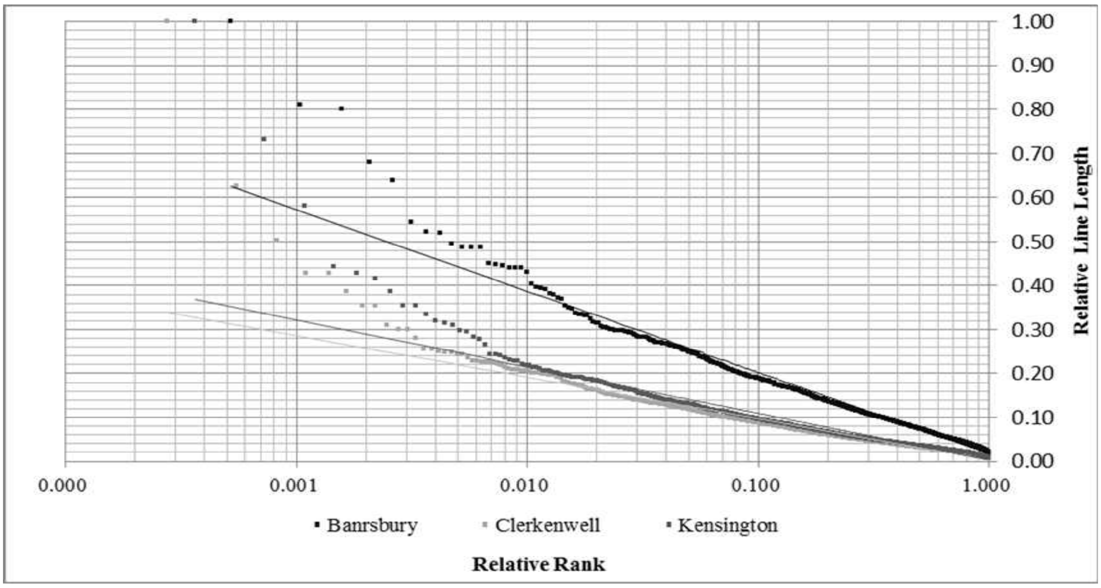
2. The Maze with an orthogonal grid organisation has the same level of correlation as the Toy Model 1: a deformed wheel.

It seems that overall layout configurational type as some effect not only on intelligibility but also on line and connectivity distribution which is not well explored in the space syntax literature. We turn to another first order index: line length distribution.

3.2 Line Length Distribution Analysis

The analysis (Carvalho & Penn, 2004) of the unconditional probability distribution of axial line length of 36 cities in 14 different countries showed that there is relatively good collapse of the data sets onto two master curves for 28 of the 36 cities studied. The study found that the length of urban open space structures displays universal features, largely independent of city size, and is self-similar across morphologically relevant ranges of scales. To understand if the Toy Models, Labyrinths and Mazes conform to this pattern we study the three standard London urban areas (Hillier and Iida 2005) and compare.

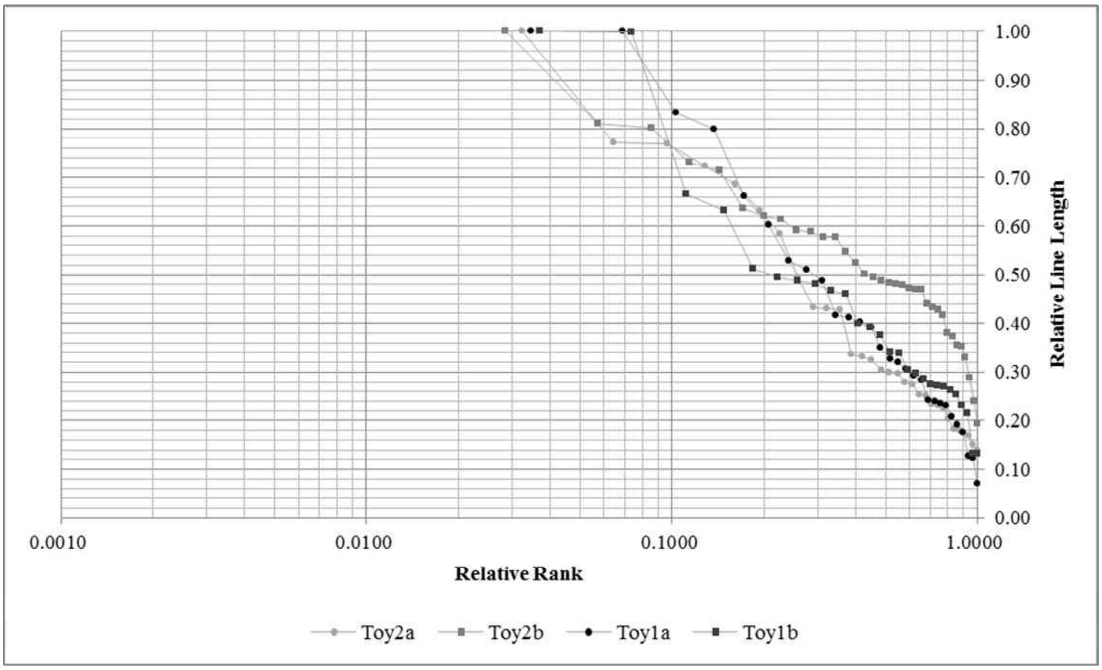
We use rank-order plot to reveal the distribution of axial line length of the above sample city areas, then define a scaled relative rank and a scaled relative line length for each axial line (Graph 3) to scale the data and make them comparable.

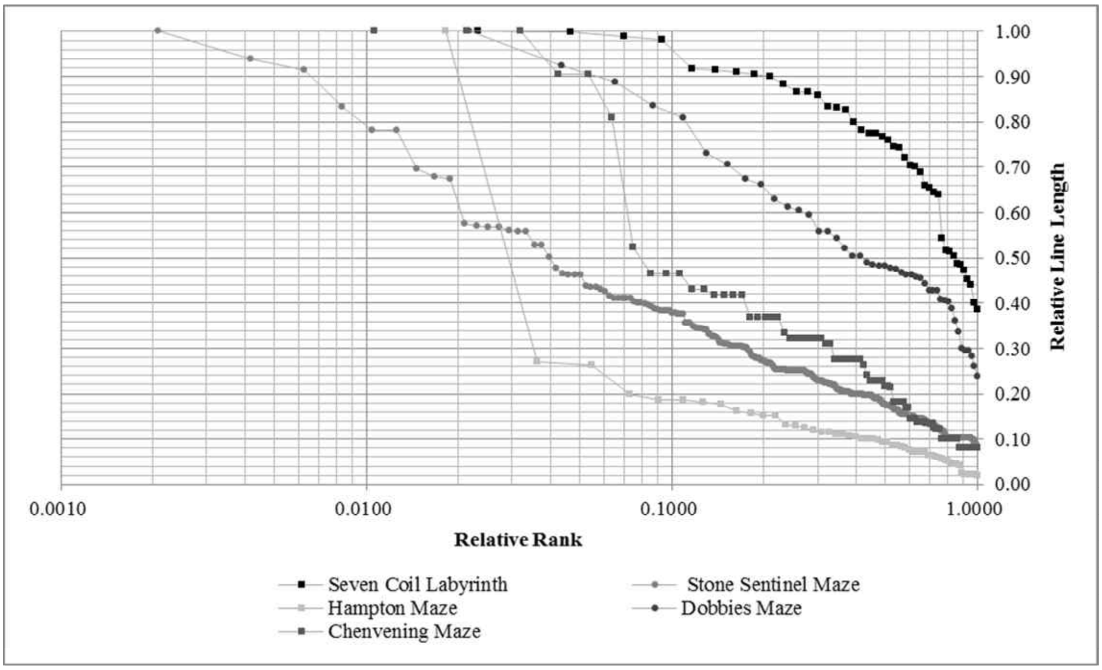


Graph 2: Rank-order plot of line length versus rank (3 urban areas in London). Log scale on X axis.

Graph 4 is the plots of relative line distribution in all of the Toy Models, labyrinth, and mazes. The curves don't show the same characteristic as of the city areas.

We suggest that the characteristics of line length distribution in the different spatial system investigated probably explain the inconsistency of intelligibility in Toy Models, Labyrinths and Mazes.





Graph 3: Rank-order plot of line length versus rank. Log scale on X axis.

4. Discussion

In this paper we investigated VGA and AGAM "intelligibility" in Toy Models along Labyrinth, Mazes and regular grids. **We highlighted some inconsistencies. Beyond VGA particular sensitivity to a real effect, to scale and edge definitions, our intuitions were that because these Toy Models, Labyrinths and Mazes have different line length distribution patterns from real urban areas these difference in distribution could be the reason of these inconsistencies**:

- When investigating the three sub-areas of London, the length of lines is internalised into the configuration of the graph (the connectivity) when there is a high correlation between line length and connectivity (Hillier, 1999b). It seems that the Euclidean distance may be implicit in the topological distance, when the line distribution has a particular distribution and configuration: intelligibility can be related to the predictability in these circumstances.

- In the mazes, for most, the correlation between line length and their connectivity is poor. In these circumstances, the topological relationship can't indict the Euclidean distance, and intelligibility can't be related to the predictability. That's why the measure of intelligibility is inconsistent in these cases. The Dobbies Maze which has both relatively high correlation between line length and connectivity and intelligibility has an orthogonal layout. Its line distribution is the one that approach the most actual urban area line length distribution profile.

- In the Toy Models the pattern of correlation between line length and connectivity for Model 1 and Model is inverted: high for Toy Model 2a and 2 b (orthogonal layout) and relatively low for 1a and very low for 1b.

- The toy models line length distribution are very similar for Toy Model 1a and 1 b while relatively different for 2a and 2b. This is consistent with the limited empirical study of

Toy model 1.

“A cognitive map is necessary for human navigation, but our cognitive maps do not have to be accurate renderings of the real world” (Golledge RG 1999). Topological distance (integration) could be the best factor that can predict the movement of pedestrians and drivers in a simple city area. Yet the angle of turn has been proved to have much to do with way finding behaviour (Sadalla and Montello, 1989; Montello, 1991; Hochmair and Frank, 2002). Within Space Syntax, Conroy Dalton(2001)’s experiments show that people tend to minimise angular distance. In Hillier and Iida 2005, it has been shown that angular segment analysis provides better analytics. **Because angular segment analysis representation breaks down the axial line into segments, “intelligibility” cannot be used directly in segmental representation.**

However, line distribution can be used in different representations whether axial or road centre line, like the ITN, (Turner 2007). Further study are necessary to investigate as to whether the analysis of line distribution pattern of actual spatial configurations could be an avenue to overcome the limit of intelligibility analysis to axial map and extend it to segment map and link map representation. There is a possibility that the role of intelligibility in normal city areas is based on the particular line distribution, on overall particular configuration pattern (orthogonal vs. radio-concentric). The distribution of line length is a first order measure that could be easily used by spatial and urban designer. The broad set of interrelated question that we set out at the beginning needs much more pointed investigations.

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