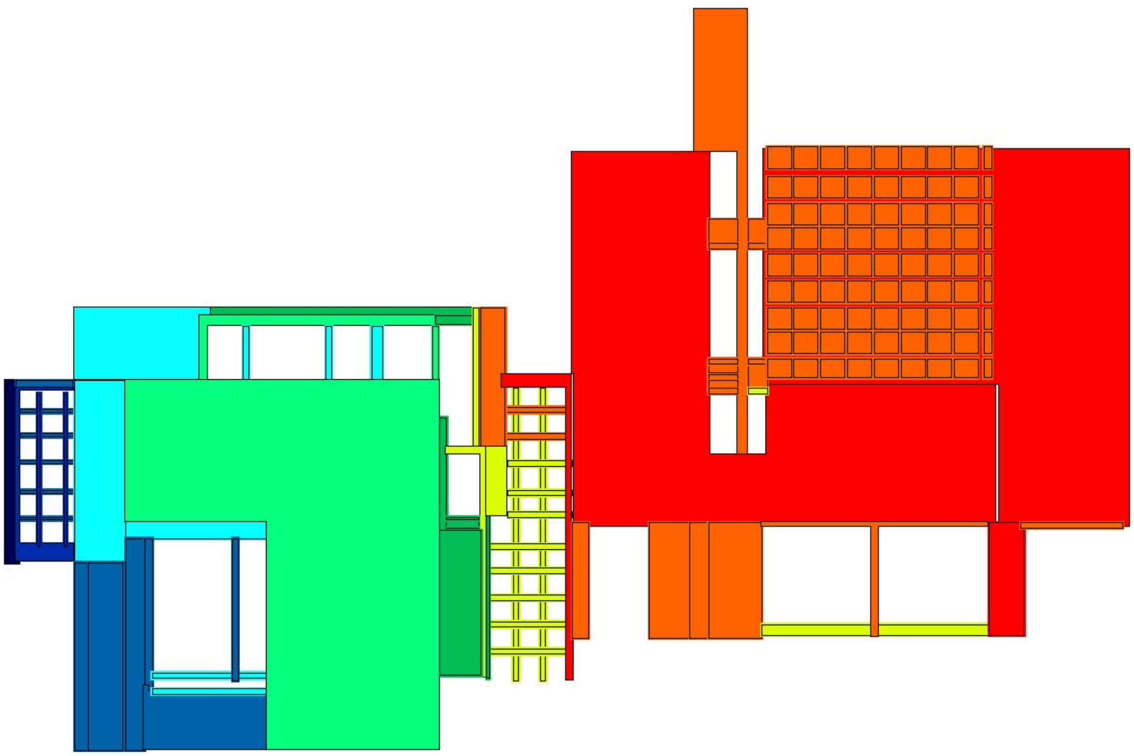
A SIMPLE GUIDE TO SPACE SYNTAX ANALYSIS AND QUICK REFERENCE COMPUTER MANUAL FOR STUDENTS

MSc/Diploma Built Environment: Advanced Architectural Studies



This document was written by Mark David Major with Professor Bill Hillier and Professor Julienne Hanson in 1998.

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Principles of Spatial Morphology

METHODS

- What is space syntax?

Space syntax is a set of techniques for describing and analysing spatial configurations of all kinds, in particular those found in buildings, town and cities. It involves four stages of thinking about space:

- identifying spatial elements - in simple houses, for example, it may be reasonable to see each room as a spatial element, but in other types of spatial complex, such as plan libre houses, or urban areas, what is and is not a space is less obvious. Space syntax proposes a number of ways of breaking up space into elements. Which is best to use depends on the aims of the analysis. This stage of space syntax is the stage of representation.

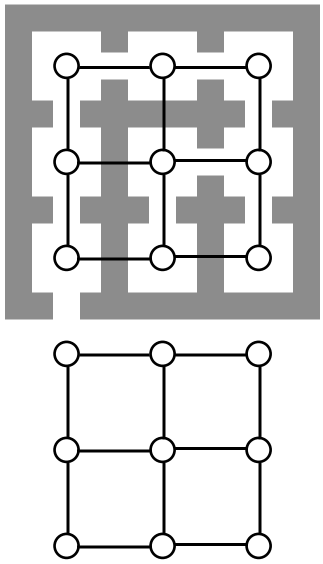


Figure 1. Adjacency Graph

- analysing the configurational relations amongst the spatial elements, however we define them. In practice this always means considering the complex of spatial relations as a graph and analysing the interrelations amongst the spaces by treating them as elements (or nodes) of a graph. This is the analysis stage;

- identifying common patterns such as those often found in the vernacular houses of different cultures, or different types of urban pattern. This is the genotype phase;

- identifying the common themes across different cultural genotypes and in this way building a cross cultural comparative analysis of spatial configuration and it relation to culture and social behaviour. This is the theory stage.

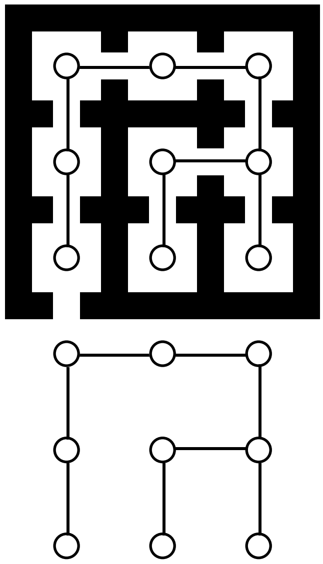


Figure 2. Permeability Graph

Coupled to these spatial analytic techniques are techniques for observing how people use space, and statistical techniques for analysing the relation between patterns of space and how they are used. We will deal with all of these in this guide, but begin first with space syntax as a set of technique for spatial analysis.

- Boundary graphs

Most space syntax analysis is centre around the idea of a graph. A graph is a way of drawing any set of relations between elements: relations of kinship, between positions in an organisation, amongst spaces, and so on. The element is always represented as a small circle, or node, and the relation with other elements as lines, or links, joining the circles. There are two obvious ways this can be applied to buildings: to make a graph of the adjacency relationship between a set of rooms (see Figure 1), which is called an adjacency graph; or to make a graph of the access relations between the spaces of the rooms (see Figure 2) which is called a permeability graph, or access graph. Obviously, there cannot be a relation of direct permeability which is not also a relation of adjacency (but not vice versa). The access graph is therefore a sub-graph of the adjacency graph.

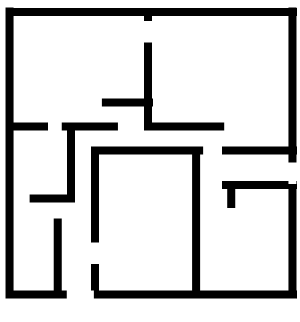
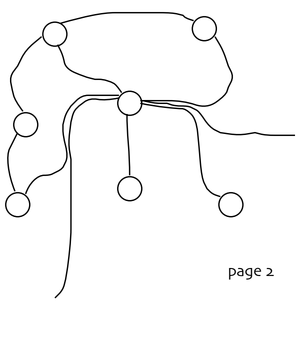


Figure 3. Plan and Boundary Graph



Most space syntax work involves permeability rather than adjacency (for review on adjacency, see Steadman's Architectural Morphology), because this is a graph of the spatial relations in a building. The simplest kind of permeability graph is one in which the boundaries of a space define each spatial element. We call this a boundary graph (see Figure 3).

- Justified Graph

In themselves, graphs are not much more informative about spatial structure than layout drawings. However, once we have the graph, there is a very useful technique for visually clarifying its structure: the justified graph. This is so important that it is usually done straight away, often without even bothering with the unjustified version. It is almost always drawn first from the carrier or space outside (see Figure 4a). Because it is so natural to draw it this way, there is a tendency to forget that the carrier is not the only possible root of a justified graph.

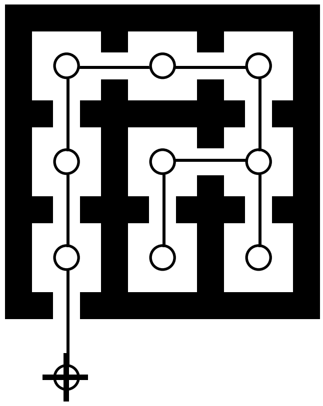


Figure 4a. Plan and its corresponding Permeability Graph

Select the root of the graph (more than one space can act as the root - you might want to treat all the rooms with a particular label as the root or, in outside space, all the houses in an estate or settlement as the root) and line up all the spaces directly connected by lines one level up the page, keeping all connections correct and keeping the graph as shallow as possible to the root (see Figure 4b). Continue to line up each next set of rooms at the next level of depth until you have made all the links and shown all the spaces in the original permeability graph. If in doubt, number up you unjustified graph from the chosen root: all spaces directly connected to it are at level one, all connected to that at level two and so on (Figure 4c). The numbers should step out from the root evenly. If you have a jump of more than one whole number between two points directly joined by a line you have numbered the graph incorrectly. If you have crossed a line more than one level of depth in the justified graph, you have drawn one or more spaces at the wrong levels of depth.

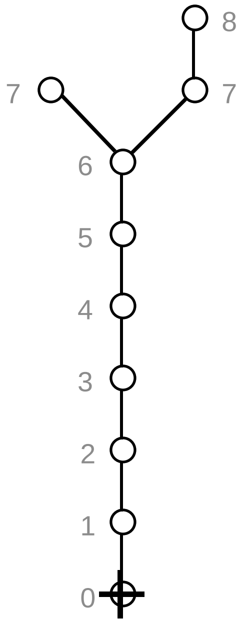


Figure 4b. Justified Permeability Graph from the carrier space (outside space) with depths indicated.

If you draw up the justified graph from different roots, you will see that the shape of the graph changes (see Figure 5). This is because spaces are normally differentially related within the configuration as a whole. It is not worth redrawing graphs to show what it looks like from each and every point, especially for large complexes of rooms, but it is often worth looking for a particularly well-connected space somewhere in the heart of the complex, and drawing it from there or even redrawing from an important labelled space like a courtyard.

Drawing graphs from different points in a configuration is a graphic way of illustrating how more integrated spaces pull the configuration close to the root and how more segregated spaces push the remainder of the configuration away. The shape of the graph captures a depth distribution from a point in an overall shape. This shape will show how examples differ in terms of depth and rings, the two fundamental syntactic properties of all spatial configurations.

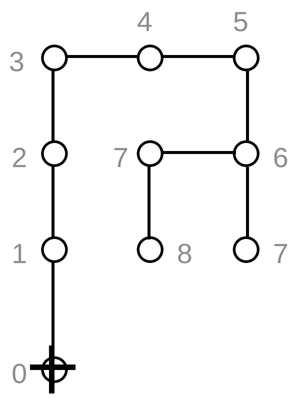


Figure 4c. Unjustified Permeability Graph from the carrier space (outside space) with depths indicated.

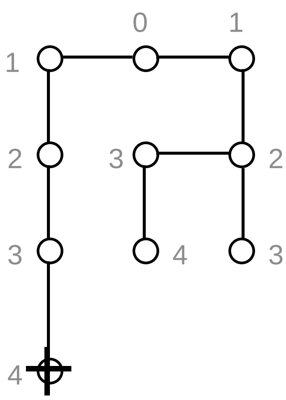


Figure 5a. Unjustified Permeability Graph with depths from the root indicated at depth 0.

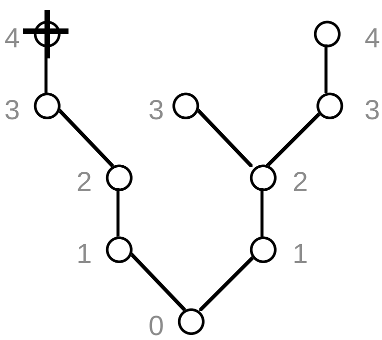


Figure 5b. Justified Permeability Graph with depths from the root indicated at depth 0.

- Calculating Mean Depth

This is the first calculation you need to do, and it helps visually to follow what is going on if you have a justified graph to do it from. However, it is not essential. You can number on the unjustified graph and, if you are in an hurry, this obviously saves a lot of time. Because you are looking at the mean depth of spaces from the root you do not include the root in the calculation at all (see Figure 6).

Multiply the total number of spaces at each level of depth by the value of the level. Obviously, the root is at level 0 and 1 x 0 = 0 anyway. Add up the remainder to arrive at the total depth. Divide by k-1 where k is the total number of cells in the graph including the root. This gives you the mean or average depth of all the other spaces from the root. It tells you how far away on average all the other spaces in the configuration are. The answer you get should make intuitive sense with the shape of the graph. If it is a bush with a long trunk and a spreading canopy, the mean depth will be high up the graph. If it is a triangular bush with a spreading base and a pointed top, the mean depth will be low down the graph and so on. The mean depth will vary with the root of the graph, since the shape or distribution of spaces within the graph will also vary with the root. This is one why reason mean depth has a limited use.

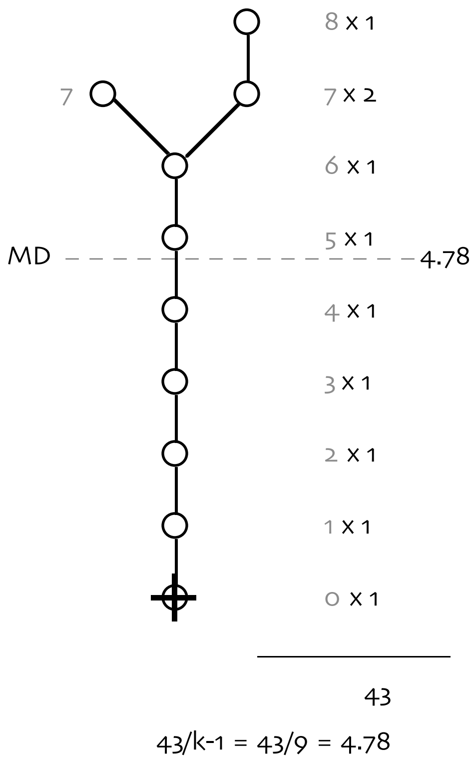


Figure 6. Calculating Mean Depth

- Calculating Integration (or relative asymmetry) values

RA (Relative Asymmetry) overcomes the problem that mean depth varies with the root to some extent, by comparing every case with the theoretical poles of a maximally shallow graph where every other space is just one level deep, and an unilinear sequence, whether each additional space adds a level of depth (see Figure 7). Like mean depth, RA varies from point to point in a configuration, depending on the depth of all other spaces in the configuration from the root. RA is calculated by a formula. You do not need to know the mathematical derivation of the formula unless you want to, but can simply apply it. The formula for RA from a space is

$$RA = \frac{2(4.87 - 1)}{10 - 2}$$

$$RA = \frac{2(3.87)}{8}$$

$$RA = \frac{7.74}{8}$$

$$RA = 0.9675$$

$$RA = \frac{2(MD - 1)}{k - 2}$$

where MD is the mean depth from a space and k is the total number of spaces in the complex. This formula relativises between a bush and an unilinear sequence for that number of spaces. For a bush with 5 spaces from the root the substitutions in the formula are

$$RA = \frac{2(1 - 1)}{6 - 2}$$

which equals 0 (because the top line is always 0). For a sequence with 5 spaces from the root the substitutions in the formula are

$$RA = \frac{2(3 - 1)}{6 - 2}$$

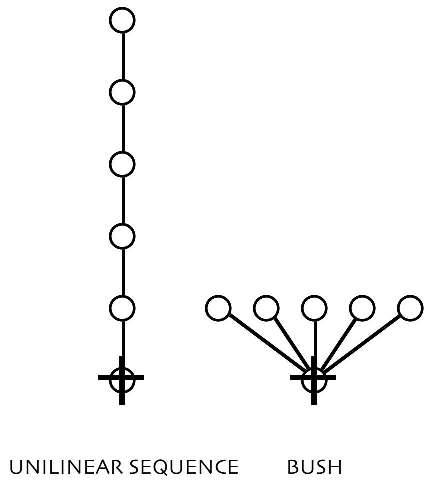


Figure 7. Calculating Relative Asymmetry (RA)

which equals 1, so the formula will always give you a number between 0 and 1 since a bush is the shallowest relation you can have and an unilinear sequence is the deepest for any number of spaces. The RA of a space expresses the degree to which it is integrated or segregated within a configuration: the more a space is integrated, the more it pulls all the other spaces in the complex close to it, the more segregated, the more it pushes all the other spaces away. Note that the property of depth is fully independent on ringiness. For a given pattern of permeability, once you have drawn the graph correctly, RA measures only depth relations in the system and a tree with that distribution of depth will be the same as a ringy system with the same distribution of spaces. We shall deal with measures of ringiness later.

- Converting to Real Relative Asymmetry

As complexes of spaces get larger and larger it is less and less likely that the shape of the graph will be either a bush or a sequence. A building of 100 rooms all in a sequence is extremely improbable. This means that if we want to compare examples with different numbers of rooms we have to eliminate the effects of the size of the complex on the RA of any space in it. We do this by comparing every case with a graph of a diamond of that number of spaces. Look up the 'D-value' (diamond value) for the number of spaces in your example and divide by that number. For external spaces we use a pyramid (p-value, or pyramid value). This seems to 'work' in practise. This means that whenever we want to compare things, especially if they are different sizes, we use RRA, not RA. With RRA, numbers go over 1, sometimes well above 1. Numbers below 1 are integrated, and above 1 more segregated, the highly the more strongly so (see Figure 8). A table of D-values is on pp 112, and a table of P-values is on pp 114 of The Social Logic of Space.

TABLE OF D-VALUES
for k spaces

pp. 112 The Social Logic of Space

5	0.352
6	0.349
7	0.34
8	0.328
9	0.317
10	0.306

RA = 0.9675, k =10

RRA = 0.9675/0.306

RRA = 3.1618

Figure 8. Converting to RRA

- Taking the reciprocal of RRA

We commonly take the reciprocal of RRA so that the numbers are reversed, i.e. higher RRA numbers mean more integration and lower RRA numbers mean less integration. This makes the numerical data is easier to understand and discuss (see Figure 9). Be warned however, that in many older studies, and in some contemporary studies of domestic space, reciprocals are not used, so that lower values mean more integration (i.e. less depth). The need to take the reciprocal really grew from the need to present correlations between integration and say movement in such a way that the idea of 'the more integration, the more movement' was intuitively clear, i.e. both increased together rather than one increasing as the other decreased.

1/RRA = 1/3.1618

Integration value = 0.316

Figure 9. Taking the reciprocal of RRA

- Functions and labels

You can treat graphs as pure space arrangements and try to describe and identify the pattern which is made by the configuration of spaces. You may also be interested in the position of particular named spaces within the configuration - labels usually come in the form of a named function but occasionally space can be labelled in other ways by decoration, by being environmentally different like an open courtyard - the property of being a transition or a use space is itself a form of labelling. You should always look at configurations with and without labels (see Figure 10).

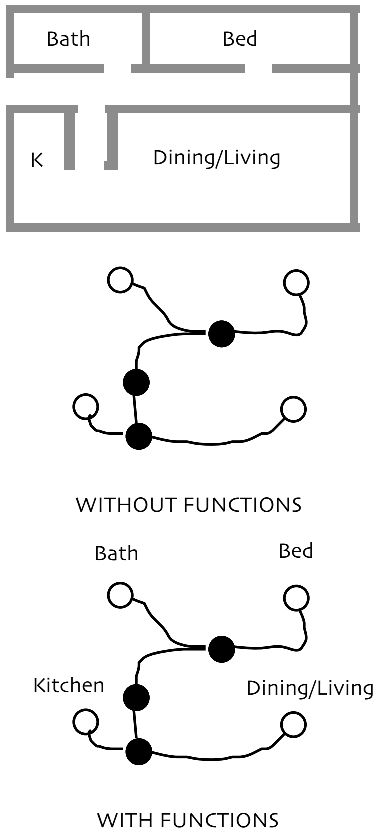


Figure 10. Simple plan with and without functions

- Inequalities and genotypes

For a single example - say a large house - it is useful to make a table of RA values and to look at the distribution in relation to use. This requires interpretation, The candidates for looking at sub-sets of different kinds of labelling on spaces are many, but the obvious ones are to do with differences between spaces and transitions, inhabitants and visitors; men and women; masters and servants; young and old; people and things; day and night; shared and individual and so on. It is always possible to pull out of the table a subset of spaces and calculate the mean RA for that function, and the degree of variation about that mean between the lowest and high RA values. Where you have a sample of plans, the process described above may lead to the identification of RRA stabilities right across the sample. The functions may show an order or integration - A < B < C - which is the same or similar in every case, though of course the actual values may well vary. Where such invariance exists we call it a genotype. Finding such stabilities is extremely improbable unless configurations are 'engineered' to make spaces consistently similar in relation to use. Where we find an RRA genotype in a sample of plans, we can be sure that space is carrying the imprint of society by building these differences into the configurations in a stable way. For a detailed description of inequalities and genotypes, see Hillier et al's 'Ideas Are In Things' from Environment and Planning B.

- Calculating Base Difference Factor

This measures the strength with which the RRA differences hold for a sample. In some cases. there may be a stable relation of A < B < C which is only weakly realised by the relative homogeneity of the RRA values. In other cases the A < B < C relation may be very strong, with the difference between the most integrated value and the most segregated value being extremely large. It is measured by a formula (which you do not need to know how to derive) adapted from Shannon's formula for measuring the entropy of a system. There is a simple computer programme (using Microsoft Works) to measure the base difference factor. In addition to measuring the strength of an RRA genotype, this can be used to measure the degree of spatial difference within a configuration by comparing the values of the maximum, mean, and minimum RRA in the same way.

$$H = -\sum \left[\frac{a}{t}\ln\left(\frac{a}{t}\right)\right] + \left[\frac{b}{t}\ln\left(\frac{b}{t}\right)\right] + \left[\frac{c}{t}\ln\left(\frac{c}{t}\right)\right]$$

This H can then be 'relativised' between ln2 and ln3 to give a 'relative difference factor' H*, between 0 (the maximum difference, or minimum entropy) and 2 (the minimum difference or maximum entropy, that is all values are equal):

$$H^* = \frac{H - \ln 2}{\ln 3 - \ln 2}$$

This relativisation is possible because the maximum H for k values is always lnk (in this case therefore ln3), and in the case of the integration measure, if one space has a value of 0, then it follows that the other two spaces must have a value of 1, in which case h is ln2, and this is the minimum possible (see Figure 11). To give a feel of this measure, the difference factor for, say, 0.4, 0.5 and 0.6 is 0.97 (that is close to 1 or very weak), whereas that of 0.3, 0.5 and 0.7 is 0.84, or considerably stronger, and that of 0.1, 0.5 an d0.9 is 0.39, or much stronger still.

$$H = -\sum \left[\frac{a}{t}\ln\left(\frac{a}{t}\right)\right] + \left[\frac{b}{t}\ln\left(\frac{b}{t}\right)\right] + \left[\frac{c}{t}\ln\left(\frac{c}{t}\right)\right]$$

Max RRA = 2.348
Mean RRA = 1.238
Min RRA = 0.968

$$H = -\sum \left[\frac{2.348}{4.554}\ln\left(\frac{2.348}{4.554}\right)\right] + \left[\frac{1.238}{4.554}\ln\left(\frac{1.238}{4.554}\right)\right] + \left[\frac{0.968}{4.554}\ln\left(\frac{0.968}{4.554}\right)\right]$$

$$H = -\sum \left[0.5156 \ln\left(0.5156\right)\right] + \left[0.2718 \ln\left(0.2718\right)\right] + \left[0.2126 \ln\left(0.2126\right)\right]$$

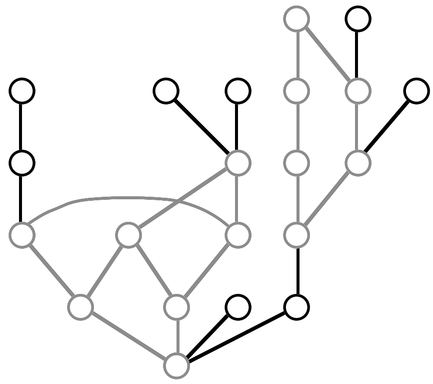
$$H = -\sum \left[-0.3415\right] + \left[-0.3541\right] + \left[-0.3292\right]$$

$$\boldsymbol{H = 1.0248}$$

$$H^* = \frac{H - \ln 2}{\ln 3 - \ln 2} \qquad H^* = \frac{1.0248 - \ln 2}{\ln 3 - \ln 2} \qquad H^* = \frac{0.3317}{0.4055} \qquad \boldsymbol{H^* = 0.82}$$

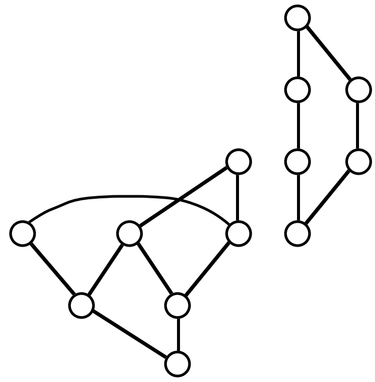
Figure 11. Calculating Base Difference Factor

- Decomposing a Graph



As well as simple measures, the visual properties of the justified graph of a complex may be exploited to yield useful information by pulling out sub-sets of the relational pattern in exactly the same way as you might pull out values from a table.

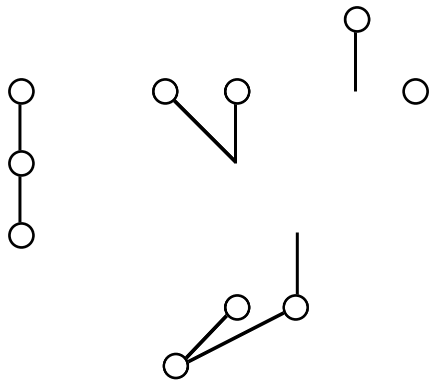
One sub-set which is worth investigation in all but the simplest cases is the relation of the distributed and nondistributed subcomplexes of a graph. Make two overlays, one showing the system of all rings in the graph; the other showing all trees (see Figure 12).



A. RING STRUCTURE

Rings may be large (with many spaces on each ring) or small (with only two or three). Rings may pass through the carrier space or be only internal. Rings may be shallow in a complex, or deep, or run from shallow to deep. There may be separate rings or intersecting rings. Key spaces may control the intersection between several rings or all rings. Similarly, the nondistributed complexes may be few and deep or many and shallow. There may be unilinear sequences or trees with several branches. They may be shallow or deep in the configuration.

The relationship of the nondistributed complexes to the distributed complexes may be of interest. All the distributed complexes may be related to one ring, to one space on a ring, or several independent rings. There may be cut points where the permeability graph would fall into two or more parts if the relation were severed. All of these visual properties require careful inspection and intelligent interpretation of the data.



B. NONDISTRIBUTED STRUCTURE

Figure 12. Decomposing the graph

- Type A, B, C and D spaces

Another useful method of decomposing a graph is by identifying what type of space it is based on it connections (see Figure 13). Spaces that make up a graph can be divided into four topological types. First, there are the spaces with a single link. These are by definition dead-end spaces through which no movement is possible to other spaces. Such spaces have movement only to and from themselves, and are therefore in their topological nature occupation-only spaces. These are termed Type A spaces. Second there are spaces with more than one link but which form part of a connected sub-complex in which the number of links is one less than the number of spaces, that is a complex which has the topological form of a tree. Such spaces cannot in themselves be dead end spaces,but must be on the way to (and back from) at least one dead end spaces. All links to spaces in such complexes, regardless of the number of links to each space, are also 'cut links' in that the elimination of any one link has the effect of splitting one or more spaces from the rest of the complex. These are termed Type B spaces.

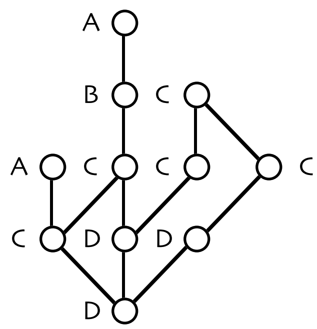


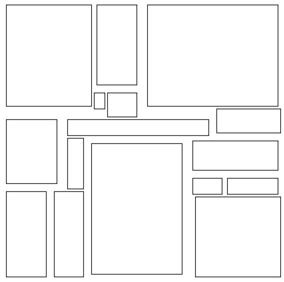
Figure 13. Type A, B, C, and D spaces

Third, there are spaces with more than one link which form the part of a connected sub-complex which contains neither Type A nor Type B spaces, and in which there are exactly the same number of links as spaces. These are termed Type C spaces. Finally there are spaces with more than two links and which form part of complexes which contain neither neither Type A not Type B spaces, and which therefore must contain at least two rings which have at least one space in common. Such spaces must lie on more than one ring, and are labelled Type D spaces. Movement from Type D spaces through a neighbour has the choice of returning by way of more than one other neighbour. A detailed discussion of the topological qualities of Type A, B, C and D spaces can be found on pp 319-21 in Space is the Machine.

- Convexity and Axiality

Boundary maps are by no means exhaust the spatial descriptions of a building. Some very complex buildings have very few bounded spaces - churches, some schools, offices and so on - yet achieve a highly complex and differentiated pattern of space. These can be analysed at the level of the plan by introducing two further kinds of spatial description. The first is 'convex' or two-dimensional description. This identifies the fewest and fattest convex spaces that cover the system, by applying a rule which says that fat spaces always prevail over thin spaces. The figure above shows an example of analysed convexity together with its graph (see Figure 14). A convex map shows the least set of fattest convex spaces in any configuration. It is can be made to break up a system of public space - like a town or villages but is more commonly used to break up space within buildings. A convex map can be drawn for a building with well-defined rooms (as in a Palladian villa), a plan libre or where there is a large open-plan room containing an arrangement of workstations or other objects. Formally, no tangent drawn on the perimeter of the convex space passes through the space at any point. Conversely, a straight line can be drawn from any point in the space to all other points in the space without passing outside the boundary of the convex space. Practically, look for the largest convex spaces and the ones which are regular shapes and easy to draw. Deal with the difficult ones last. Remember the 'fatness wins' rule and if you have to 'steal' from a neighbouring space in the second dimension, then you must not do so, but rather you should maximise the two dimensional property of both, and not of one at the expense of the other - you should in other words optimise the area-perimeter ratio of both shapes (see Figure 15).

The second is called an 'axial' or one-dimensional description. This identifies the longest and fewest straight lines that cover all the convex spaces in the plan. The figure to the right shows an example of analysed axaility, together with its graph (see Figure 16). Axial maps are discussed in detail below.


CONVEX BREAK-UP

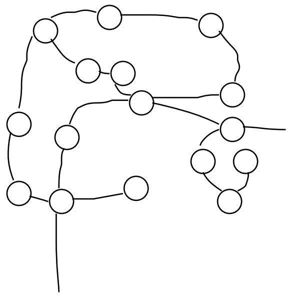
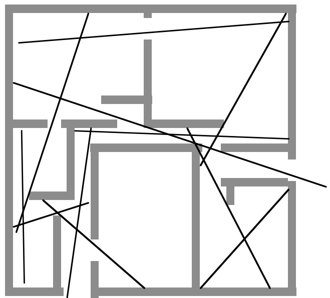

CONVEX GRAPH

Figure 14. Convexity


AXIAL BREAK-UP

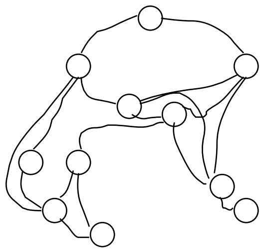

AXIAL GRAPH

Figure 15. Axiality

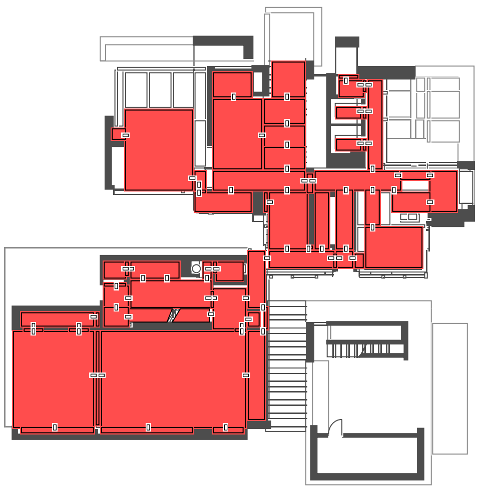


Figure 16. Convex map with thresholds in Eisenman's House X

- Transitions and spaces

Some spaces are used for obvious purposes. The purposes of others seem mainly to separate use spaces from one another, or to put spaces together through a system of circulation, depending on how you look at it. Halls, corridors, lobbies, stairwells, etc. may fall into this latter category of transitions. You may wish to identify these on your permeability graphs. Usually we colour them solid black (see Figure 17).

What ever convention you use, make a note of it in a key. As stated before, you can treat graphs as pure space arrangements and try to describe and identify the pattern which is made by the configuration of spaces or by the position of particular named spaces within the configuration - labels usually come in the form of a named function. Remember that the property of being a transition or a use space is itself a form of labelling.

- Level of Resolution

There is always some level of resolution at which you have to decide whether or not to take some aspect of a layout into consideration. Thick walls, so thick that actual doorways are almost like separate spaces, projecting piers and small changes in level are typical cases of anxiety in mapping. Should they be shown or disregarded? If in doubt do 'with and without' versions and compare them to see how much difference it makes (thinking that you might have to do this usually eliminates much of the angst, and ensures that you only fuss over variations where they are likely to be important to the argument). Once made, record decisions about the 'level of resolution' and apply them consistently across the sample. 'With and without' comparison itself is a technique for revealing properties in the fine-tuning of space. This problem in buildings is usually directly related to the problem to be analysed. If you are interested in an architect's intentions during the design process in developing a distinctive architectural form than it may be necessary to take all spaces (including 'trivial' spaces) into account since these spaces are an outcome of design decisions by the architect. However, if you are interested in the relationship between spatial layout and family (as indicated by functional labelling) in a culture or across cultures then it may not be necessary to take into account these 'trivial spaces' (see Figure 18).

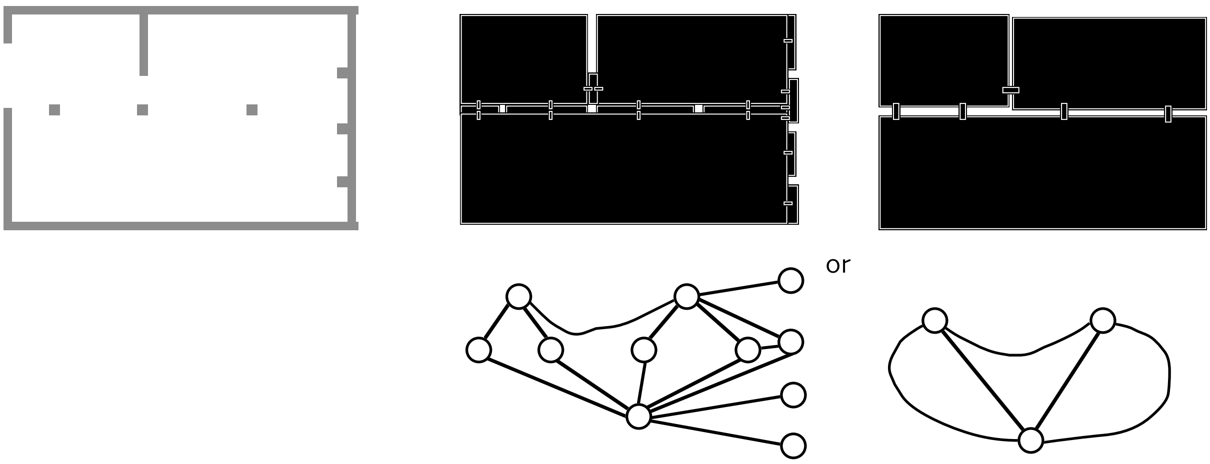


Figure 18. Which level of resolution?

In urban space, you will need to decide at what point to begin to ignore minor declivities as with buildings. This has to be done both convexly and axially, and consistently.

The resolution of the convex break up of a system can be problematic, particularly where spaces are designed to be small-scale with many twists and slight changes of level, in the vicinity of entrances where a degree of fine-tuning may be used consciously or unconsciously to subdivide space, or where space is particularly large-scale and amorphous as in a modern housing estate layout with only a few freestanding elements at ground level. All of these difficulties can be resolved by doing a 'with and without' analysis to identify the degree of difference which taking 'fine tuning' into account makes to the layout.

Minor declivities in the axial breakup of space may be even more important. A facade may protrude so as just to obstruct the view down a street. On the other hand, the opposite property may exist. 'Just-about' axially is an important property of many settlements. In some cases as you align your ruler against the facades of buildings to find the longest lines of sight and access, which pass through a space, you will begin to notice that lines just about get through. There will occasionally be a doubt as to whether or not to allow a line to 'get through.' Often this can occur with a degree of regularity which suggests that the effect is not accidental. Where the line 'just about' gets through you should allow it to do so. Also, remember you pen thickness in drawing an axial line will be several metres (when considered in scale) whereas a true mathematical definition of a line means that its has no width. Therefore, if in doubt let the line through because 'on the ground' it will almost certainly will (see Figure 19).

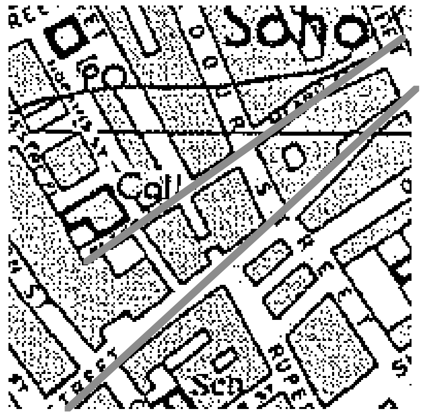


Figure 19. 'Just about' axiality

Whether facades obstruct the view or whether 'just about' axiality actually exists may be a subtle feature of both towns and of open plan buildings. Because it is a subtle effect, you may have to inspect the plans carefully to establish whether or not lines get through. If in doubt, and if at all possible, always make an on-site inspection to check whether or not they do! You should watch for this property in modern buildings and in deformed grids, since if you draw the line down the geometric middle of a space or a street you will not measure this effect, whereas if you use the alignments of the facades to position the longest line which skirts the facades you will pick it up.

You must be rigorous and do the axial break-up 'blindly' - i.e. not try to build in the effects you think may be important, like making axial lines strike important facades at right angles where a longer line might reach the facade but impinge at an open angle, or breaking an axial line at a street intersection where there is a longer line which passes right through the junction. You must take the longest lines regardless of geometry, to yield the fewest and longest lines which cover the system and pass through all convex spaces.

On the other hand, urban space is almost always characterised by very small-scale spaces which are 'attached' to main space of the street, for example blank spaces form by the irregular shape of the building facade. These form trivial convex spaces which are almost always ignored in the construction of an axial map (see Figure 20).

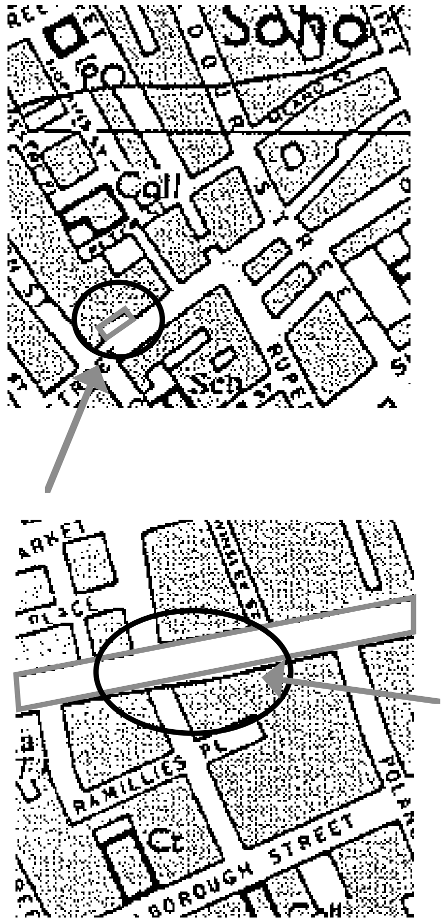


Figure 20. 'Trivial' convexity

The axial map is a basis for all sorts of counting: axial line index, axial
connectivity, ring connectivity, and axial ringiness are all described on pp 103-104 of The Social Logic of Space, but are often not invoked.

- Elementary tricks with samples of plans

To aid visual inspection in samples of plans the following procedures may prove useful.

Arrange the set in ascending size order from the one with the fewest nodes in the graph to the one with the most. Syntactic size differs from metric size - a small building may have many rooms and vice versa. It may be useful to look at the relation between syntactic size and metric size to see the degree to which spaces is subdivided in this way. A crude but simple measure is to divide the metric size of the plan by the number of spaces in the graph.

Arranging a set of examples in syntactic size may show that cases are duplicated. It may be necessary to eliminate information to discover this. You should always look at the sample with and without labels. You should be looking to establish the following: is there a process of syntactic growth by which it is possible to show the relation in which each next cell has to be added in order to move from the small to the large examples; is it possible to reduce the apparent variety of the sample by identifying cases at the same number of cells which are identical and if so to what extent is this the case; is there a single syntactic generator of all the examples or do they fall into syntactic types which will be some permutation of depth and rings?

- Axial Map

The axial map is the workhorses of urban analysis. The aim here is to identify the fewest and longest straight lines of sight and access which cover the system and pass through every convex space. Practically speaking, human intuition and the computer use the same method to break up space axially, which is by reference to the facades which describe the structure of spaces under investigation. Back a ruler against the building line of the facades which define a long line of sight and access and move it about until the ruler strikes the facades on the opposite side of the street. Maximise the length of this line. Start with the longest lines and work down to the smaller ones. All convex spaces should be crossed and all rings in the system made. There should not be any repetition of axial lines. Make sure you do not stop an axial once it connects to another line because the property of overlap in axiality is an important component of the way cities are put together. If you do you will be adding depth to a system which is unrealistic and if you consistently stop axial lines and do not take into account overlaps the resulting axial map will be incorrect.

The axial map has measures attached: axial articulation compares the number of axial lines with the number of buildings in the system, and grid axiality looks at the number of axial lines in the system compared with the number that would exist for a perfectly regular orthogonal grid with the same number of islands. These measures are described on pp 99 of The Social Logic of Space and are used where you wish to compare examples (see Figures 21 and 22).

Figure 21a. 'Constructing the axial map

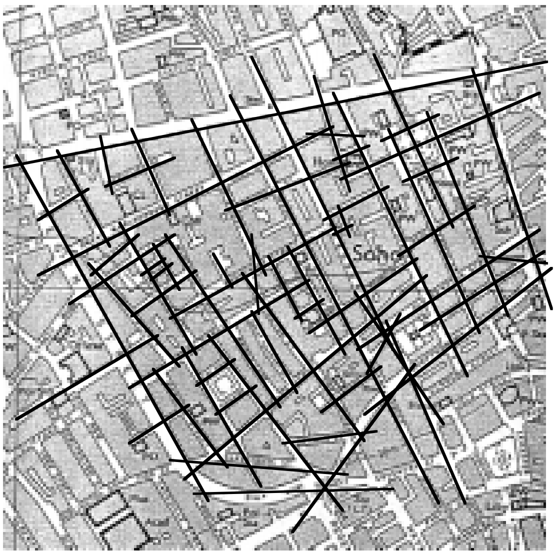
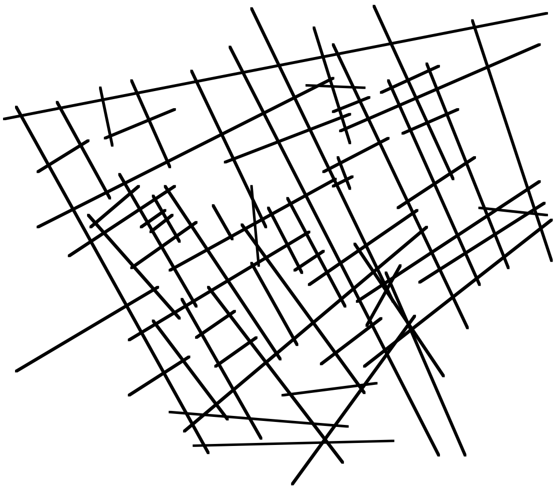


Figure 21b. Axial map



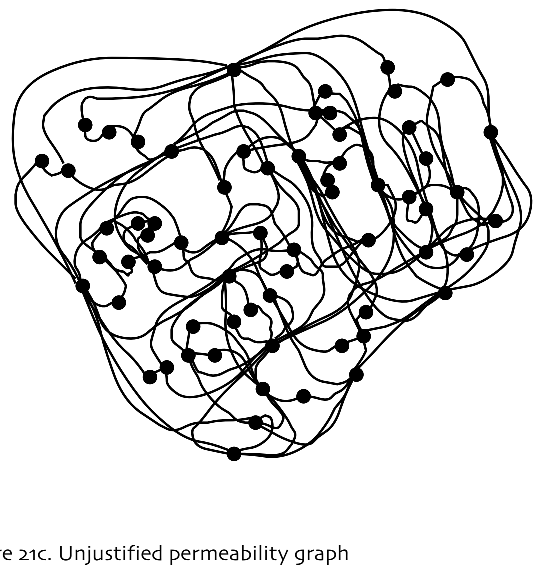


Figure 21c. Unjustified permeability graph

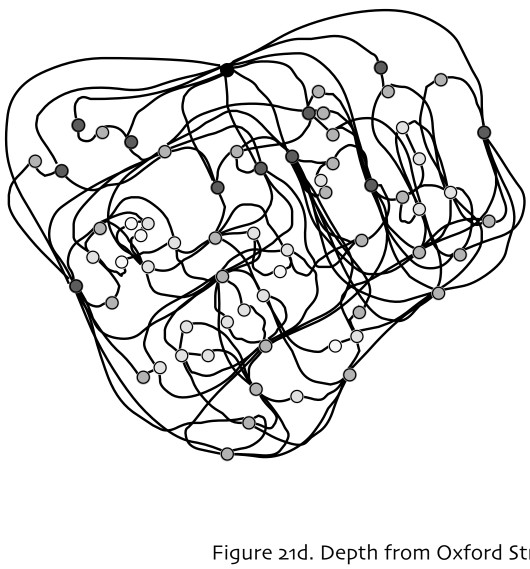
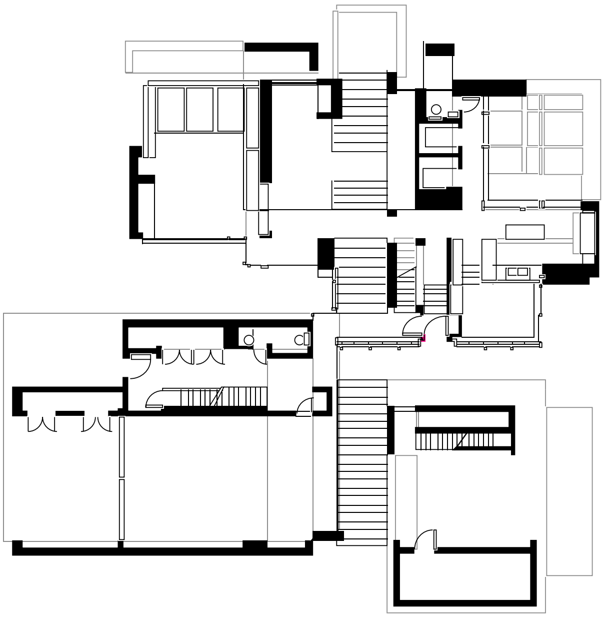
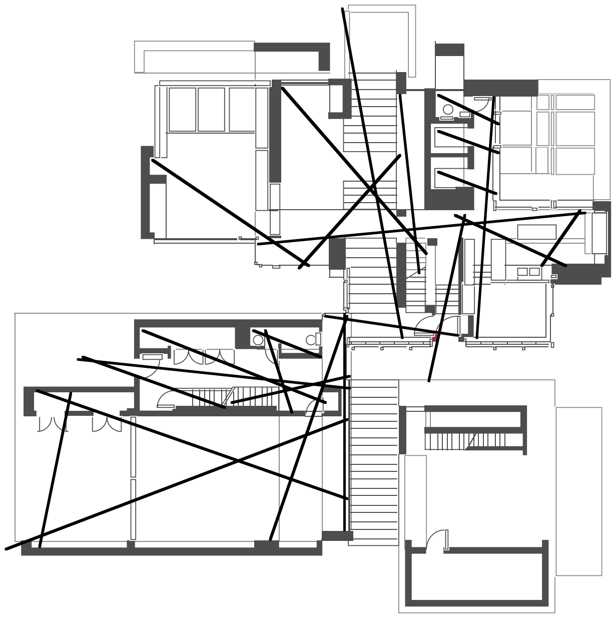


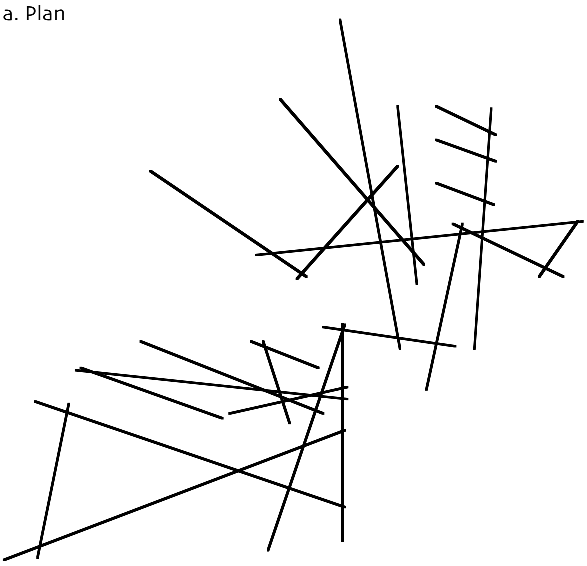
Figure 21d. Depth from Oxford Street

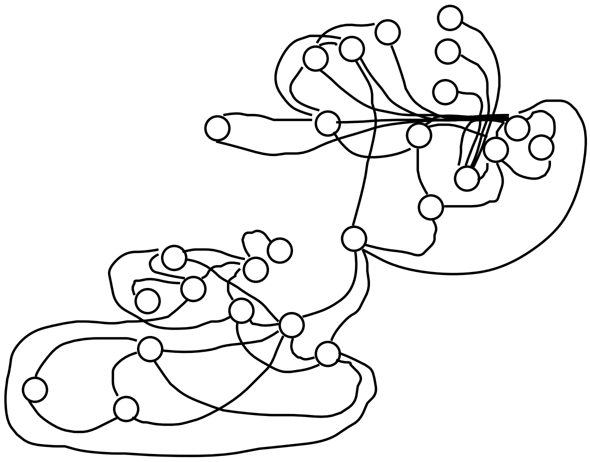




a. Plan

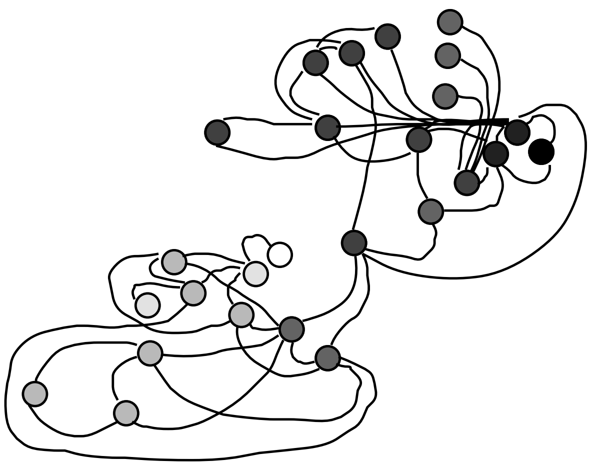
b. Axial breakup, without outside and trivial spaces (closets, etc.)





c. Axial map

d. Unjustifed permeabilitygraph



e. depth from the kitchen

Figure 22. Peter Eisenman's House X

- Strategic axial nodes

These are strategic points where two or more long, strong axial lines converge so that it is possible to gather a great deal of information about the global structure of a settlement or building by locating yourself (or a building, or building facade) there.

Where three or more axial lines converge in a large space or wide street there may produce a 'trivial' ring - trivial because it exists only by virtue of the meeting of lines in open space and not because there is anything built in the middle - at the intersection. We often colour is solid to distinguish it from a ring which surrounds an island or block of built of space. Where these trivial rings occur where long lines join there will be an enlarged strategic node or zone of space where a strategic strong point in the settlement or building exists.

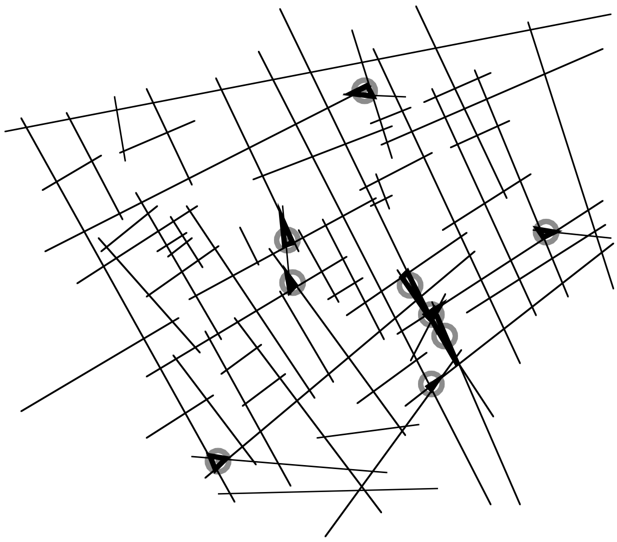


Figure 23. Strategic axial nodes

- Spatial Measures

Past research using these methods have consistently found the importance of the axial map in influencing those patterns of activity and occupation that are commonly set up in complex buildings and cities.

One key property of the axial map is integration. Integration measures the degree to which each line in the map is present on the simplest (fewest changes of direction) routes to and from all other lines. Normally integration is measured for each line in a system in relation to all other lines. This is termed integration radius n (infinity), or global integration, A version of integration, termed integration rad. 3 or local integration, restricts the measurement of routes from any line to only those lines that are up to three lines away from it. This measures the localised importance of a space for access within a particular part of a building or urban network.

The simplest measure of all is connectivity, which measures the number of lines that intersect with each line in the system, whilst depth measures the number of changes of direction any line in a system is away from a selected line or lines.

Another measure, 'control' is calculated by first allocating each axial line in a system the value of 1. Each line then distributes this value evenly among its immediate neighbours. For example a line with four immediate neighbours would give a value of 0.25 to each. In return, the line that gives its value of 1 away also receives values from each of its neighbours according to their own connections (which would give the line in this example a control value of 2). In this way, a long line with many neighbours which themselves are poorly connected will obtain a high control value. The poorly connected lines will obtain a low control value. Typical high control areas are nurses stations in hospitals.

Once a building plan has been represented as an axial map and the values of the various measures have been calculated for each line it is possible to use the numbers describing properties of the way the network of spaces connect together to form a system as a means of investigating the effect of spatial design on anything that can be located on plan. Patterns of movement and space use for example, or even crime locations.

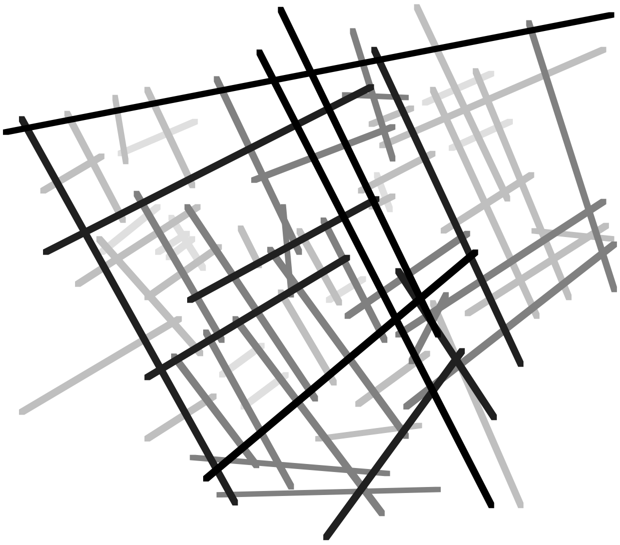


Figure 24a. Global integration, radius = n

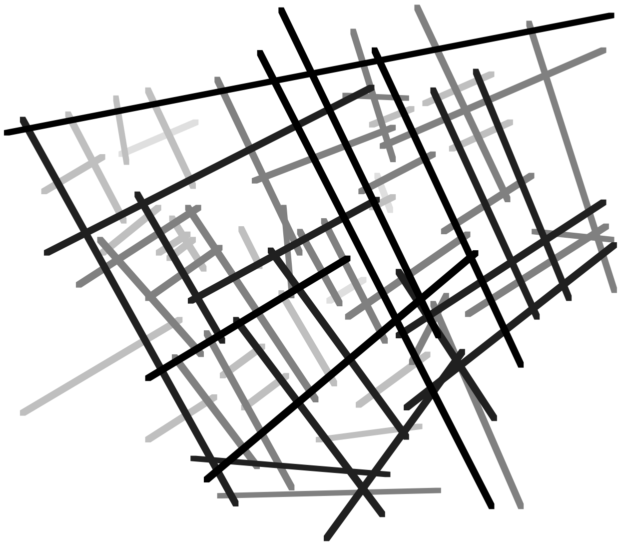


Figure 24c. Local integration, radius = 3

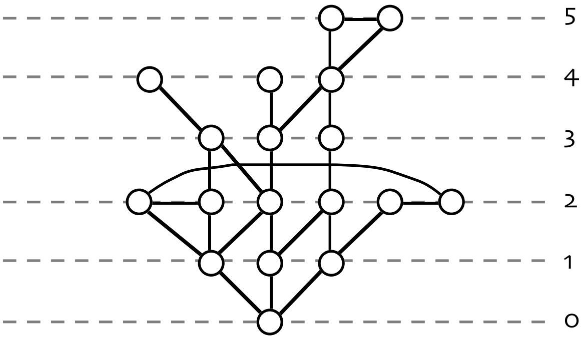


Figure 24b. Calculatin global integration, radius = n

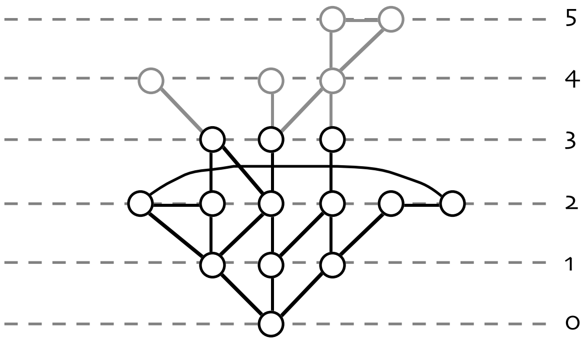


Figure 24d. Calculating local integration, radius = 3

Figure 25a. Connectivity

Figure 25c. Control

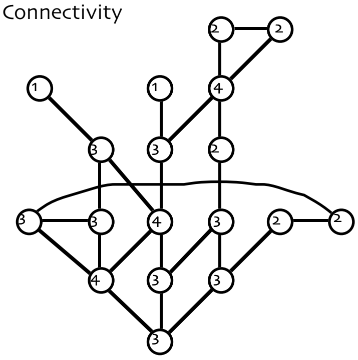


Figure 25b. Calculating connectivity

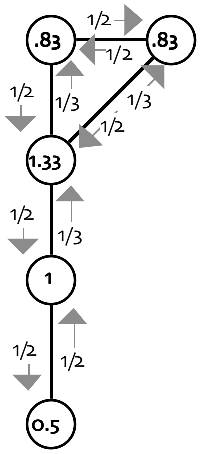


Figure 25d Calculating control

- Depth from the outside

This gives a useful handle on the way in which a place structures through-movement and movement into the centre from the outside. Number axial lines at the edge and penetrating from the edge at depth 1, those directly connected at depth 2 and so on until all lines are numbered with respect to the outside. The syntactic spread of depth values can be compared with geometric depth from the periphery since often they are not the same thing. In some settlements axial lines penetrate rapidly to the geometric heart of the town and areas around the perimeter are several steps away from these penetrating lines, so that they are syntactically deep - many turnings away - than the geometric centre of the town. With a large town, this can be shown graphically by the use of colour, using the measure Point Depth, in Axman.

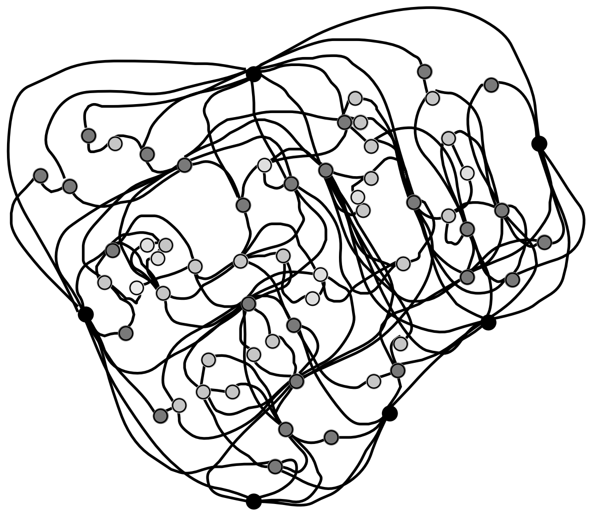


Figure 26. Depth from the perimeter

- Steps to cross the system

A variation on depth from the outside, this is looked at by performing 'journeys' across the system from the key routes defining the outside, or whatever you choose. Often the number of steps to cross from one side of a place to the other differs from one compass direction to another so that the settlement is more easily traversed with a few steps in one direction than another. In some cases 'journeys' through the system may take many axial steps - many more than around the edge. A comparison can be made between syntactic and metric steps to cross the system and metric distance were the journey were to take the form of the straightest possible 'as the crow flies.' This will compare the diameter of the system with half the perimeter of the system. Were the route to be straight through the centre then it would take one axial step to cross, irrespective of metric length, compared with three axial steps around the edge and a metric distance greater than the diameter of the system at right angles to the route. The more the

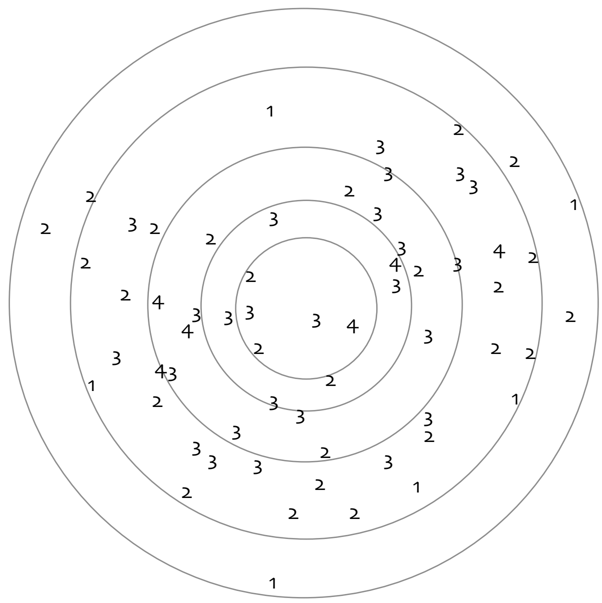
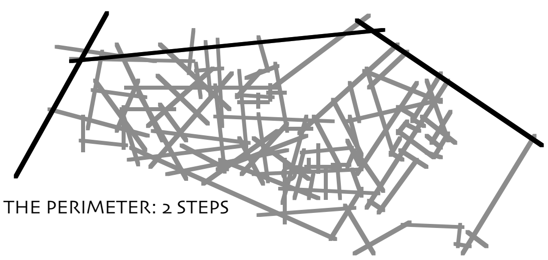
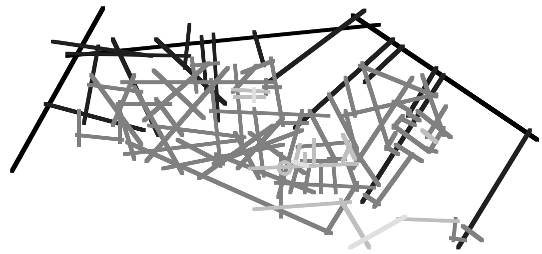


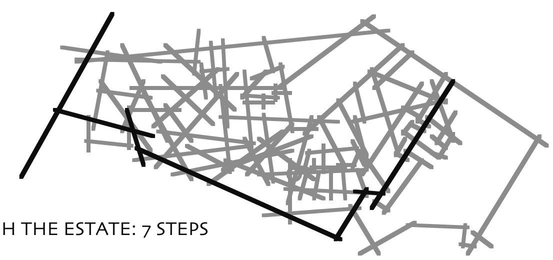
Figure 27. Geometric and syntactic depth



AROUND THE PERIMETER: 2 STEPS



POINT DEPTH FROM PERIMETER ROUTES



THROUGH THE ESTATE: 7 STEPS

Figure 28. Point depth, shortest east-west route

cross route twists and turns the metric distance and axial steps increase. We do not measure this at present, but only describe it, though a 'maze' measure is conceivable. It is a key feature , particularly of estate housing layouts where it is easier to go around the main street grid than to walk through the heart of the estate.

- Axial integration of convex spaces

This is:

$$\frac{\text{the number of axial lines}}{\text{the number of convex spaces}}$$

and shows the extent to which convex spaces are linked axially by long lines of sights and permeability. It is also know as a 'string of beads' or a 'kebab effect.' A limiting convexity=axiality maximised case is a perfectly regular orthogonal grid. The opposite is a maze, where convex=axiality, but minimally. This measure is a useful one, both for looking at the mean axial integration of lines in a settlement and also for describing the properties of particularly long, strong axial lines. A comparison of the maximum, mean and minimum values will show the variety of 'coaxial' effects in a settlement - in some cases there may be a great deal and in others hardly any.

- Depth from building entrances

One representation which is useful is to note the convex depth from building entrances. This can be done directly on the convex map or unjustified graph. If you do it on the unjustified graph rather than directly, then you can decompose the graph into those adjacent and permeable spaces where both have doors opening onto them. In some cases this will make little difference to the pattern of links. In other cases the number of links between spaces will reduce dramatically, so that most of the circles in the graph are not joined together. The converse representation connects only those spaces which are unconstituted by building entrances. In some cases these are isolated from each other so the map remains a set of unconnected circles. In other cases, unconstituted spaces connect

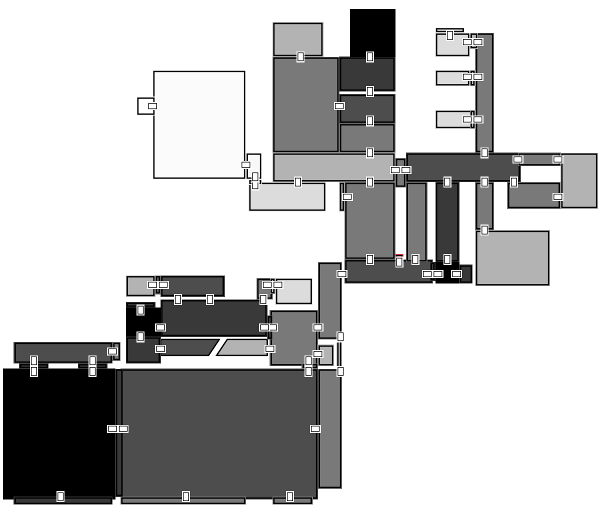
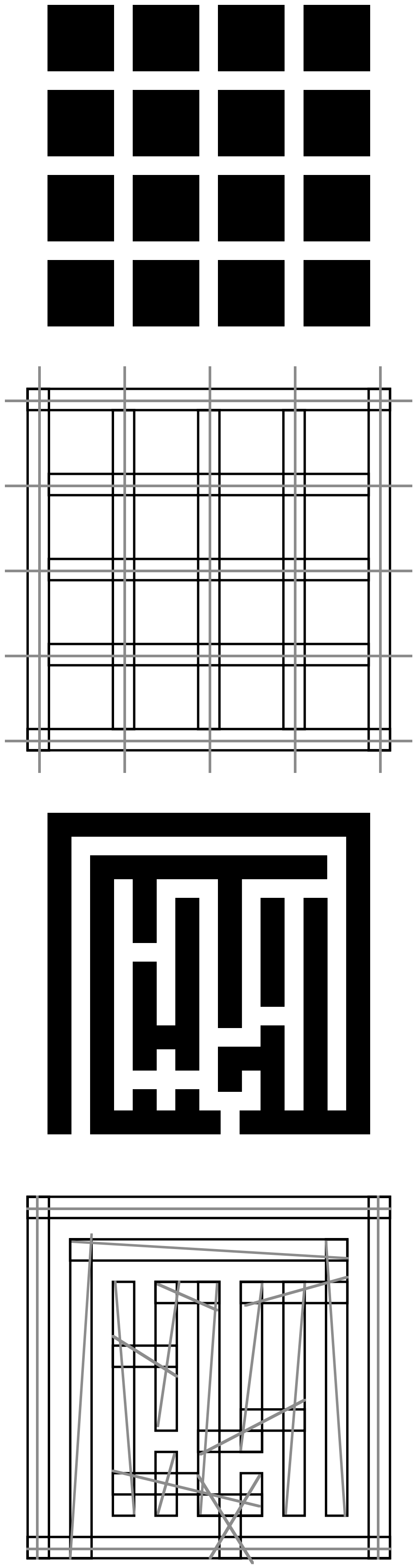


Figure 30. Depth from building entrances



axial lines = 20 $\quad \frac{20}{22} = 0.91$
convex spaces = 22

Figure 29. Axial integration of convex spaces

together in groups - in extreme cases forming a system of circulation remote from building entrances.

As with other graphs, these can be justified from the outside or any other point within the system. For large towns the structure of the justified graph is too complex to yield much useful information in the small-scale, although the work we are contemplating on the shape of the graphs should improve our understanding of their properties. Meanwhile, as with graphs of small objects, the main use of this form of representation is to show general shape properties from different key points.

- Interface map

A graph can be converted into an interface map by marking the relationship of convex spaces to building entrances, showing each building as a solid dot and each entrance by a line joining solid (representing building) to circle (representing convex segment). A converse interface map shows only those relations of adjacency and impermeability. These maps are only drawn where they can show dramatic visual results.

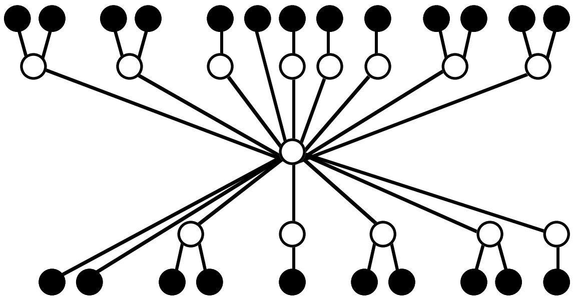


Figure 31. Typical interface map for a traditional street pattern with some front gardens

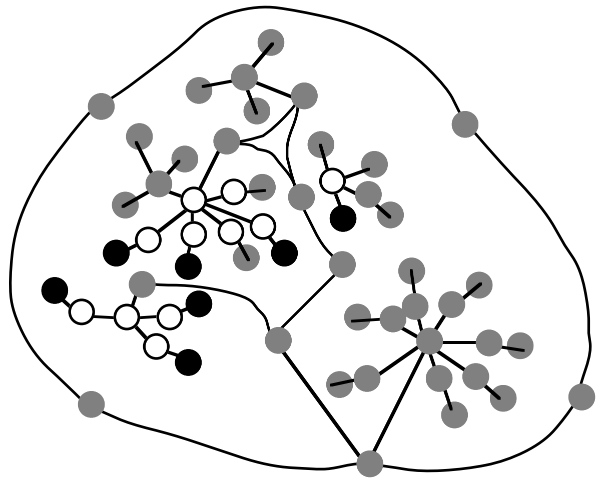


Figure 32. Typical interface map for a modern housing estate pattern with front gardens and unconstituted spaces indicated in grey

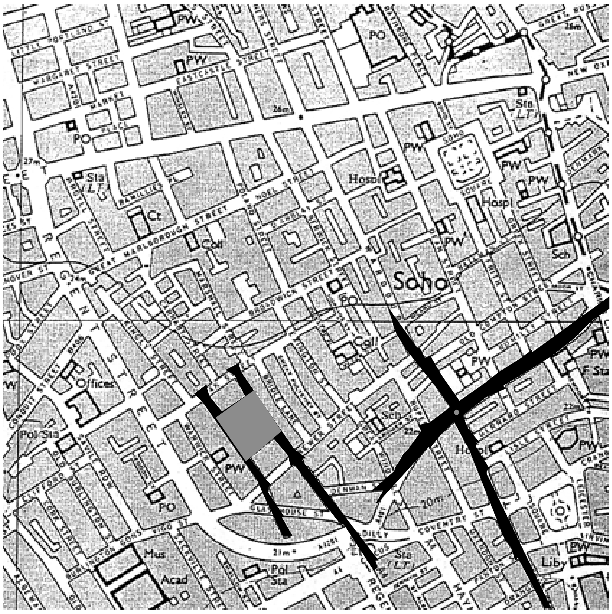
- Isovists (or Visual Fields)

The isovist of a space is a representation of everything that can be seen directly from it - imagine it as a beam of light spreading out and illuminating all the space it reaches and casting a shadow wherever objects stand in its path.

Unlike convex or axial maps, whatever you use as the basis for making the isovist - convex isovist, axial or line isovist, isovist of a core of spaces, isovist from a point or facade - a complete set of isovists from every source will overlap. Partly for this reason, we do not make isovists of every space (however this is defined) in the system, although overlap is theoretically important and we may eventually make more use of it.

It follows that the basis for selecting a set of isovists varies with the problem to be addressed - it cannot be done mechanistically. You may wish to look at the isovists of the largest 2-D or 3-D spaces, the longest axial lines, the isovists of important buildings or key spaces, major facades, or the most integrated spaces. You may want to compare them as a set of isolated shapes or to look at the spread and coverage of one or several isovists within a building or space configuration.

Benedikt has arrived at measures for describing the shape of isovists. You may need to make use of these or other measures. One key variable is the extent to which the isovist is constrained by boundaries (walls in a building, buildings in a settlement) as opposed to having a boundary made in continuous space, beyond which point you lose the view of the isovist source. Through MiniCad 5.0 or 6.0 it is possible to bring a whole series of metric measures into play with regards to isovists shape and size, i.e. area, perimeter area, average diameter, etc...



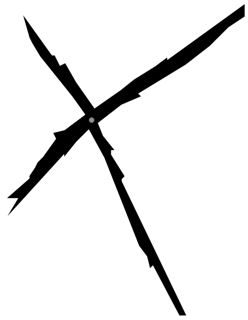


Figure 33a. Point isovist

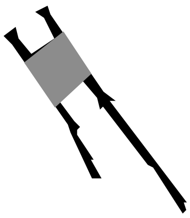
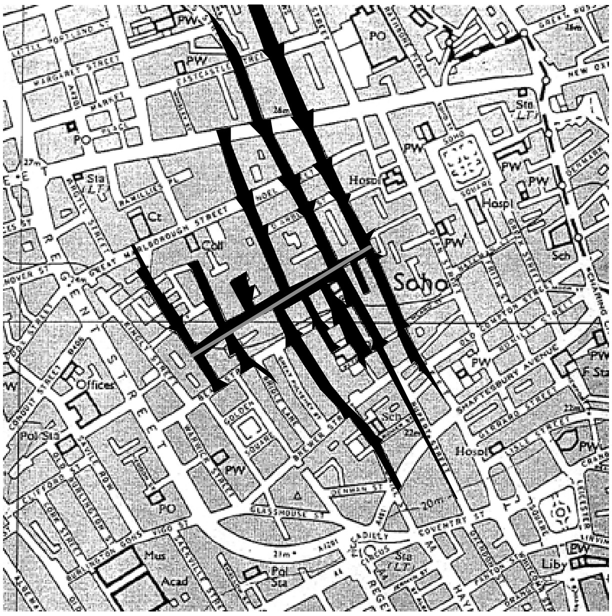


Figure 33b. Convex isovist



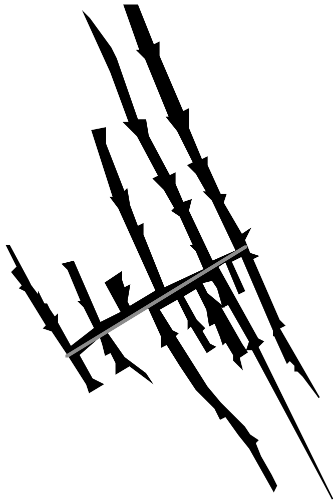
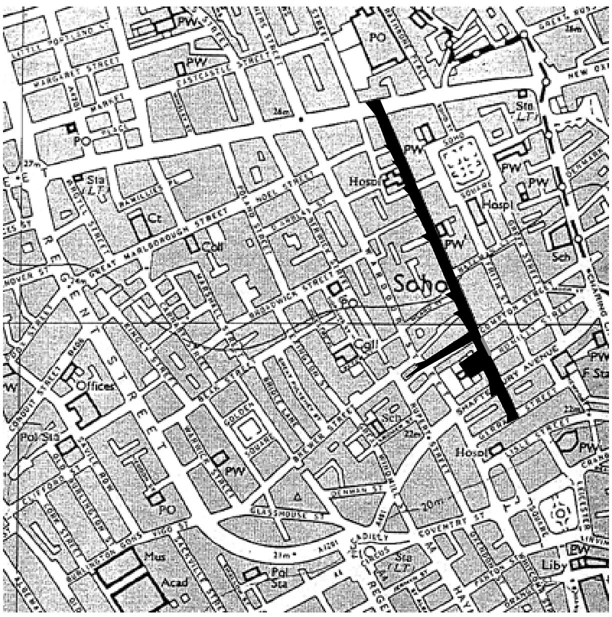


Figure 33c. Axial isovist



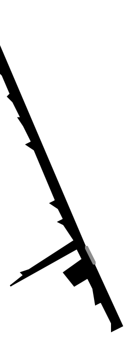
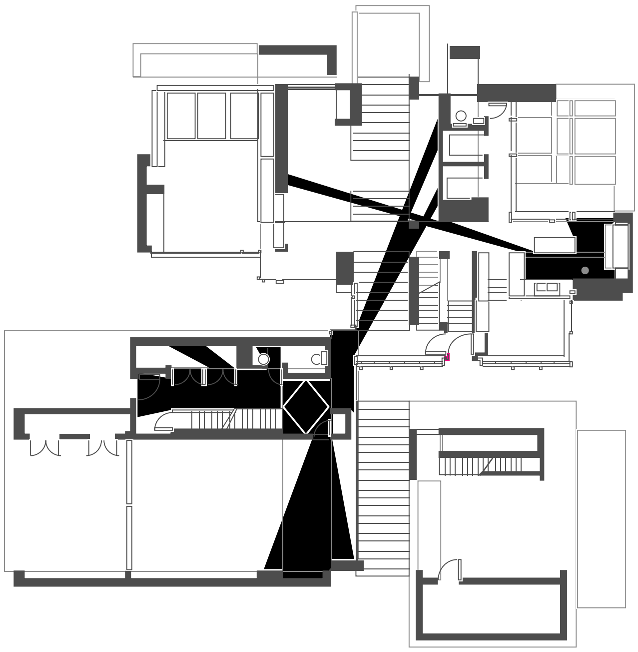


Figure 33d. Facade isovist



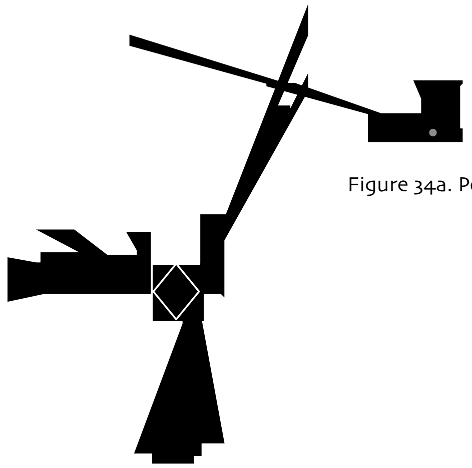
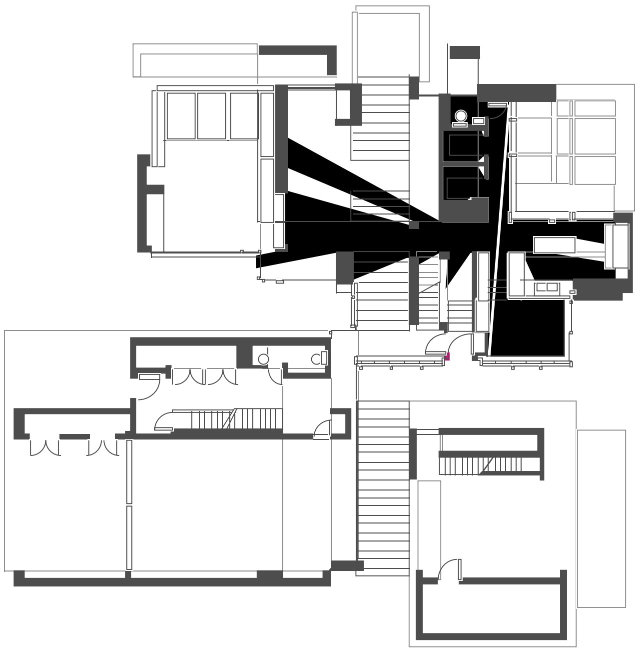


Figure 34a. Point isovist

Figure 34b. Convex isovist



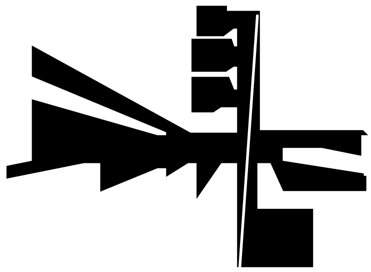
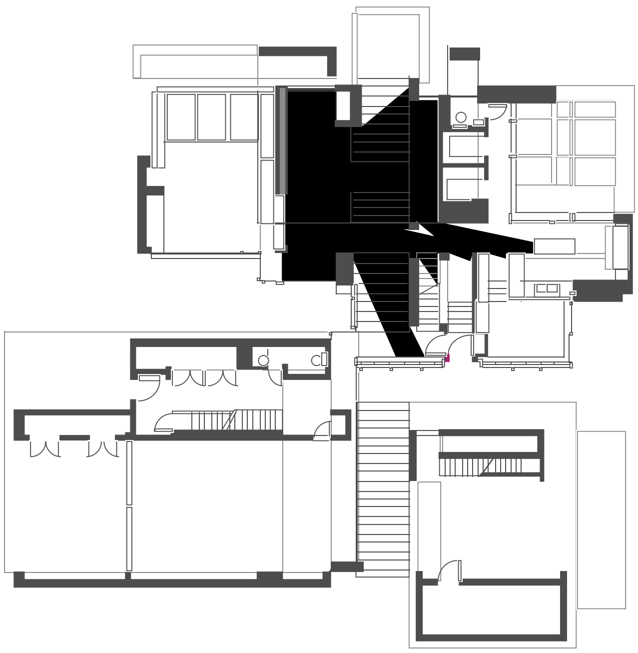


Figure 34c. Axial isovist



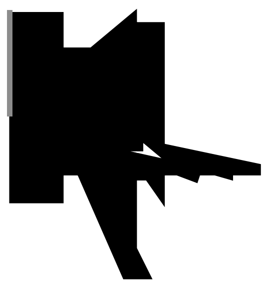
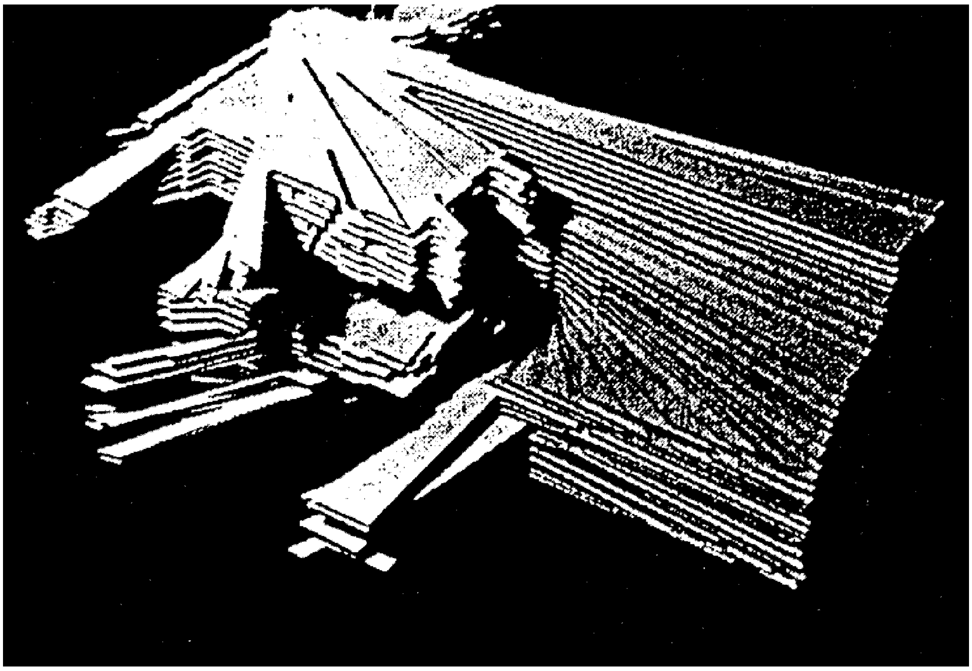


Figure 34d. Facade isovist

- Minkowski Models and other isovists

The idea of Minkowski models is to cut the isovist sequence in card or board (or for those of you more daring in the computer using Pangea) and stack it up in levels - space is horizontal, time is vertical. This models an environment unfolding as different parts become visible to the observer and shows a new field at a higher level in the model. It is an attempt to animate perception. Dickon Irwin drew 'flip books along the axial lines to illustrate the same thing. More recently, Stonor and Kourti have constructed computer 'movies' using MacroMind Director of isovist sequences along a path through urban space. All of these ideas are attempts to show a relation between where you are and what you see. All are characterisations of overlaps in space, of which there are infinitely many. Non-Overlapping Descriptions of Space. We need a 'least set' of replicable spaces to represent invariance as opposed to infinite variety. Convex and axial maps are about non-overlapping, invariant representations of space. For a more detailed discussion of isovists and Minkowski models see Benedikt's 'To take a hold of space: Isovists and isovist fields' from Environment and Planning B.



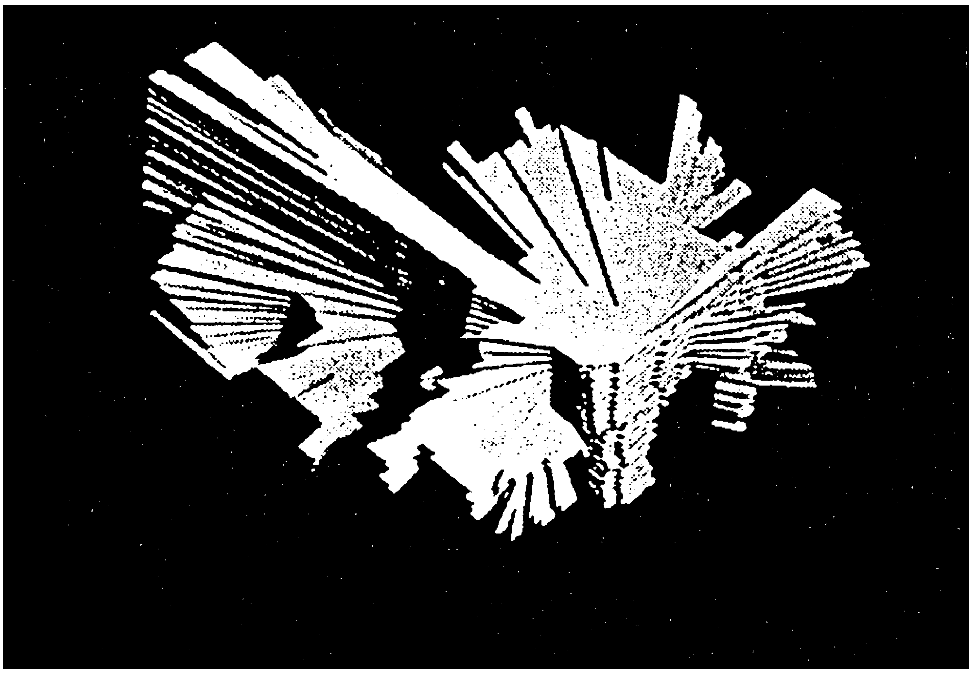


Figure 35. Minkowski models

- SpaceBox:
  Complex Convex Models and All-line Analysis

A convex map shows the least set of fattest convex spaces in any configuration. It is can be made to break up a system of public space - like a town or villages but is more commonly used to break up space within buildings. A convex map can be drawn for a building with well-defined rooms (as in a Palladian villa), a plan libre or where there is a large open-plan room containing an arrangement of workstations or other objects.

The computer can also draw a representation of all the lines that pass through the open space of a system. This gives bands of lines rather than a single axial line. It shows a larger two dimensional extent of the axial line system than the least set. The degree to which the axial system is itself 'thin' and linear or 'fat' and convex is different in different settlements. A regular grid is an extreme case where this property of 2-D axiality is maximised.

All line axial maps basically pick up, using the vertex of each built form modelled, all the potentials for movement - not only linearly along a space but also the segmental opportunities for movement, for example in a grid. This is why an all line axial analysis of a regular grid will show a symmetrical centre-to-edge and centre of the edge-to the corner distribution of integration. This is because there are more potentials for segmental movement at the geometric centre of the regular grid rather than at the edges. This could partially explain why people moving through semi-regular grids 'cut across' the grid - i.e. the psychological benefits of moving in a theoretical straight line and because they are moving toward more integration at the centre of the grid where there are more potentials for continuing their journey by 'cutting across' the grid.

However, remember that the computer programme Space Box generates more complex representations of convexity and axiality. This may be helpful, particularly in resolving difficult cases. The computer finds the vertex of each building and then defines the opposite quadrant of the vertex - the region of open space lying within two lines projected from the edges of facades continuing each vertex. It then draws the straight line from the vertex to the nearest point on another island within the opposite quadrant so defined. Be warned that this can be useful at times but also confusing, especially in highly articulated layout where a great deal of convex overlap exists, for example in a complex plan libre. Convex maps also form part of the basis for modelling complete spatial models of buildings using PESH software. This is discussed below.

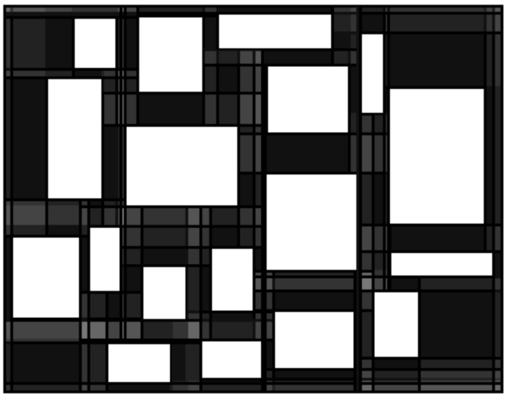


Figure 36. SpaceBox drawing convex spaces

Figure 36. SpaceBox drawn convex map

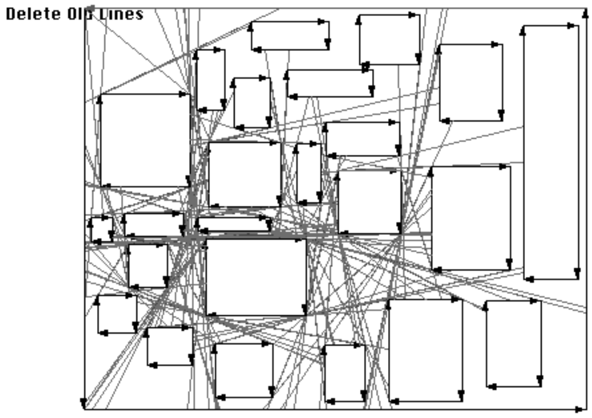


Figure 37. SpaceBox drawn axial map

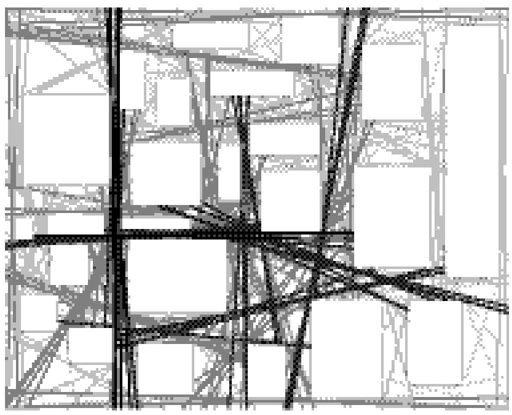


Figure 38. SpaceBox drawn axial map

- Complete Spatial Models (PESH)

With the recent development of the PESH software by Nick 'Sheep' Dalton many more variations on these techniques involving multiple layered analysis have become possible. For example, it is now possible to do calculate integration of the combined convex and axial models by simply layering one on top of the other. In fact, it is theoretically possible (if not always practically possible because of computer power) to analyse two, three or four layers of representations at once (for example, convex map, axial map and interface map with strategic isovists from major buildings like churches or schools).

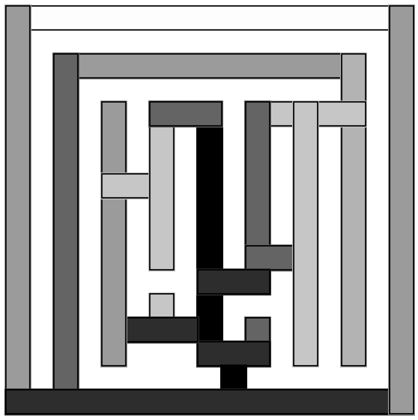


Figure 39. PESH analysis of a maze

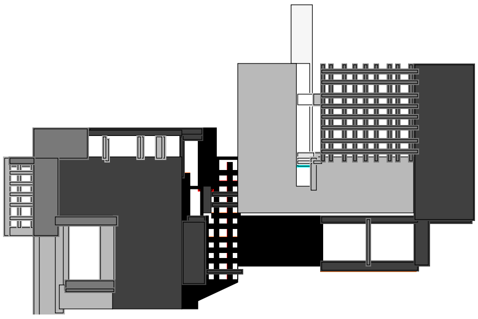


Figure 42. PESH analysis of west facade of House X

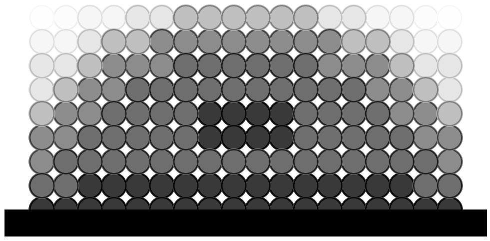


Figure 40. PESH tessellation analysis (with 'earth line')

Much of this analysis is largely dependent on the problem to be investigated, however, there is a great robustness in adding additional layers of information to the model which can be represented as graphs. Basically that is what the computer does - it takes all the 1-D or 2-D objects in the model and represents them all as circles with the objects and connections (i.e. layered connections one on top of each other or any kind of overlap) as lines between the circles. It then justifies the graphs from each object and calculates integration, connectivity and local integration in the usual manner. This is still new so many variations of analysis are possible. To date, analysis using PESH has included building retail floor areas in the model, building height and complete spatial models of the interior of buildings. Basically any analysis is possible of data which can be represented as 1-D or 2-D objects and transformed into a graph.

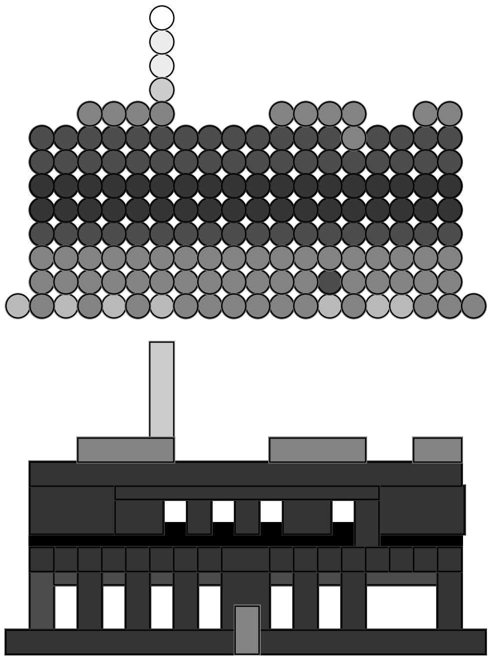


Figure 41. PESH layered tessellation analysis with large-scale objects 'peeled' off

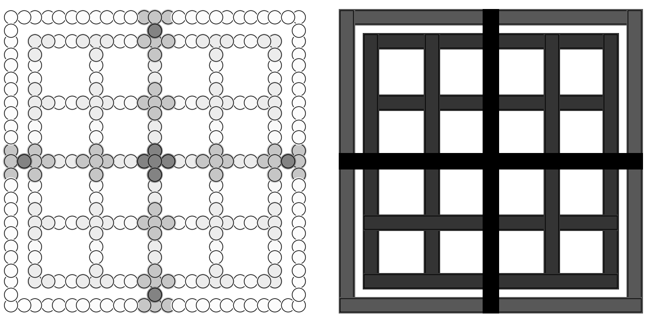


Figure 43. PESH layered tessellation analysis of perfect grid (with walls) with axial lines 'peeled' off taking into account metric integration

One highly experimental form of analysis arising out of the use of PESH has been layered tessellations. Layered tessellation represents the micro-scale of space or composition in the form of squares or circles (for example 1 square metre) over which then large-scale objects are layered (for example the axial lines or convex space in spatial configurations, or as the dominant composition elements of a facade like window fenestration or projections of built form). These large-scale objects can then be 'peeled' off the model to see what the pattern of integration is for the micro-scale objects. Layered tessellations can be used to represent attributes of metric distance and recent research by Hillier has begun to present findings on the importance of metric integration in spatial layouts, see Space is the Machine and Therefore the Grid. A few studies have been done using these techniques to begin to raise questions about the composition of facades. Long-term plans will include software development of PESH which will allow the analysis of the facades of a building as a 3-D whole so as you 'move' around the building the compositional pattern of integration changes with your 'view.'

- Pangea (Intelligent Architecture)

Pangea is a tool to help you think in three dimensions. Pangea is simple to use, yet powerful and extremely versatile. It allows you to create, manipulate, analyse and walk around a world composed of 3-D scriptable objects with attributes. An intuitive and enhancable user-interface simplifies access to Pangea's sophisticated functions, with which you can easily build application-specific problem solving tools.

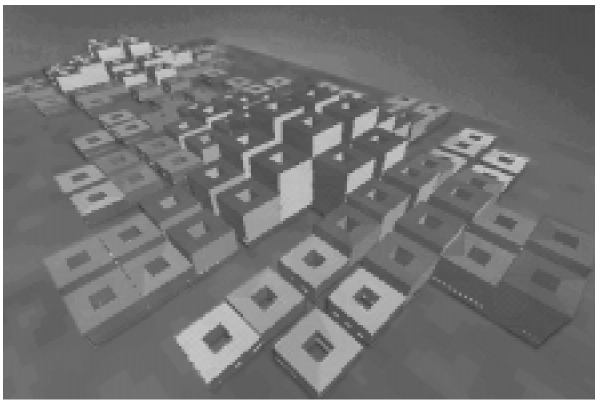
You can analyse a range of variables in a world using cameras. Each camera view can display a particular variable, so when the design is changed the views update themselves, thus allowing you to watch the dynamics of how altering the form of the design affects its functional outcome. You can quickly assimilate key issues, identify potential conflicts, and make informed decisions. Objects themselves can have both attributes (standard and user-defined) for you to easily embed data, behaviour and intelligence within the object, and scripts which allow the object to respond to you, or other objects, through messages. To help you structure information in models, Pangea lets you group objects into collections, and allows similar objects be 'clustered' together using an automatic inferencing tool.

The Intelligent Toolkit features are fully adaptable and hybridisable, and support the use of neural networks, genetic algorithms, rule based systems, and other evolutionary techniques. You can import and export data as well as communicate with external applications, thus allowing existing and future software to be fully integrated.

Pangea provides fluidity of modelling and movement using 3-D shapes that communicate, respond and learn. Artificial worlds can be built and programmed to respond graphically to the user's moves, so bringing greater intelligence to the design and management of the built environment.

Pangea has been developed at University College London by the Intelligent Architecture project funded by the Engineering and Physical Sciences Research Council (EPSRC) and Department of Trade and Industry (DTI) in collaboration with:

Avanti Architects Ltd • Bovis Construction Ltd • Broadgate Properties PLC • Criterion Software Ltd • DEGW London Ltd • Oscar Faber Consulting Engineers Ltd • PowerGen PLC • Qualum Ltd • Richard Rogers Partnership • Smallworld Systems Ltd • The Bartlett, UCL • Department of Computer Science, UCL



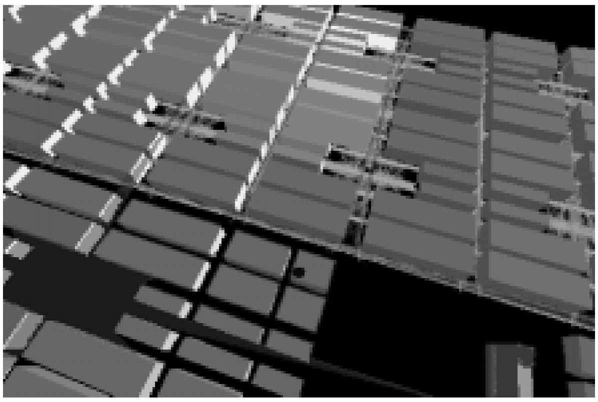


Figure 42. Pangea (Intelligent Architecture)

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