SPACE SYNTAX METHODOLOGY

This teaching guide was first released in 2013 under
the joint authorship of K. Al Sayed, B. Hillier, A. Penn and A. Turner.
The front matter was amended in its current form in 2018;
not for citation and with K. Al Sayed as the principal author

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SPACE SYNTAX METHODOLOGY

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A teaching guide for the MRes/MSc Space Syntax course (version 5),
Bartlett School of Architecture, UCL

CONTENTS 4

A PRACTICAL GUIDE TO SPACE SYNTAX METHODOLOGY

Introduction

This 'Practical Guide to Space Syntax Methodology' is intended to give an accessible explanation of network representations of space for the purpose of architectural and urban research and design. It provides some basics on Space Syntax theory, both as a conceptual framework and as a tool for thinking the relationship between space and society via the UCL Depthmap[1] programme, alongside explanations of the concepts underlying spatial analyses models and descriptions of how these analyses are applied in the context of architecture and urban research.

[1] Copyright @ University College London2000-2010 all rights reserved. Programme by Alasdair Turner.

The guide takes students from the basics of spatial analyses techniques, observation methods and data modelling through to more advanced agent-based modelling. The techniques are described roughly in the order they were first discovered, and the guides indicates how they may be used in research and also suggests how such tools might inform best practices in architectural and urban design. Theoretical introductions for each chapter explain the representations, models and constructs of measurement. Exercises and tips throughout the book allow students to practice using UCL Depthmap.

This guide is a supplement to the UCL MSc/MRes workshops that run throughout the two terms of the academic year. Each workshop will involve slides introduction and exercise demo as well as question and answer sessions, which need to be studied alongside this manual.This guide is intentionally parsimonious in its academic content. You will need to consult the academic literature to understand the theories underpinning the methods described here.

What is Space Syntax?

It starts with a certain description of the spatial architecture of buildings and cities. In Space Syntax, spaces are understood as voids (streets, squares, rooms, parks, etc.). Voids are defined by obstructions that might either constrain access and/or occlude vision (such as walls, fences, furniture, partitions and other impediments). Buildings are composed of a series of spaces; each space has at least one link to other spaces. The structural properties that comprise these spaces and links might have an embedded social meaning that has implications on the overall behaviour of human habitat (figure 1.1).

The same description might also apply on an urban scale. Cities are aggregates of buildings held together by a network of spaces flowing in-between the blocks. This network connects a set of street spaces that form together a discrete structure. The structure is the optimum result of shortest paths from all origins to all destinations in the spatial system. It is what holds it all together. It has an architecture, and by this we mean a certain geometry and a certain topology, that is, a certain pattern of connections (figure 1.2).

Buildings can have different structures that relate strongly to their functionality. Prisons are normally hierarchical reinforcing power and control in the form of access and visibility relationships. Prison cells appear at the very end of these hierarchies. On the contrary, museums are made up of continuous spaces that follow some sort of narratives. These kinds of building organisations have their recognisable spatial characteristics. To expose these spatial characteristics we use graph-based representations and measure their structural properties. The structural properties might then be indicative to how the social organisation functions.

On the urban scale, spatial structures can take an organic, uniform or deformed shape. These universal types of urban grid vary in the way they interweave connecting the part-whole structure. They emerge on different scales, and as a result, have different geometric properties. Topological and geometric analysis of urban grids using UCL Depthmap software helps us understand the configurational structure of urban spaces and its potential impact on social behaviour and economic activity (Hillier, 1996a).

1750

1850

2000

Figure 1.1. The transformation of the Guildhall of the City of London. Source: Kinda Al_Sayed, 2007 @UCL.

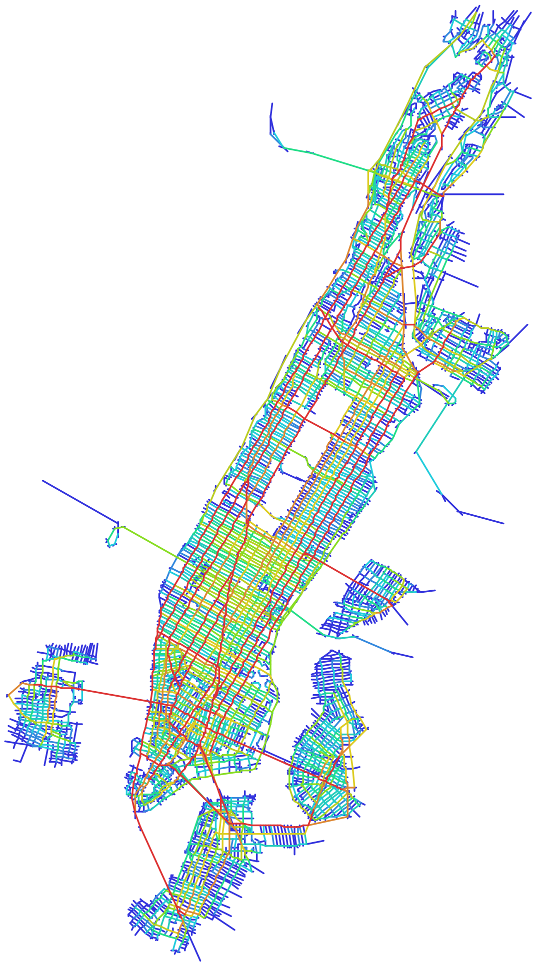
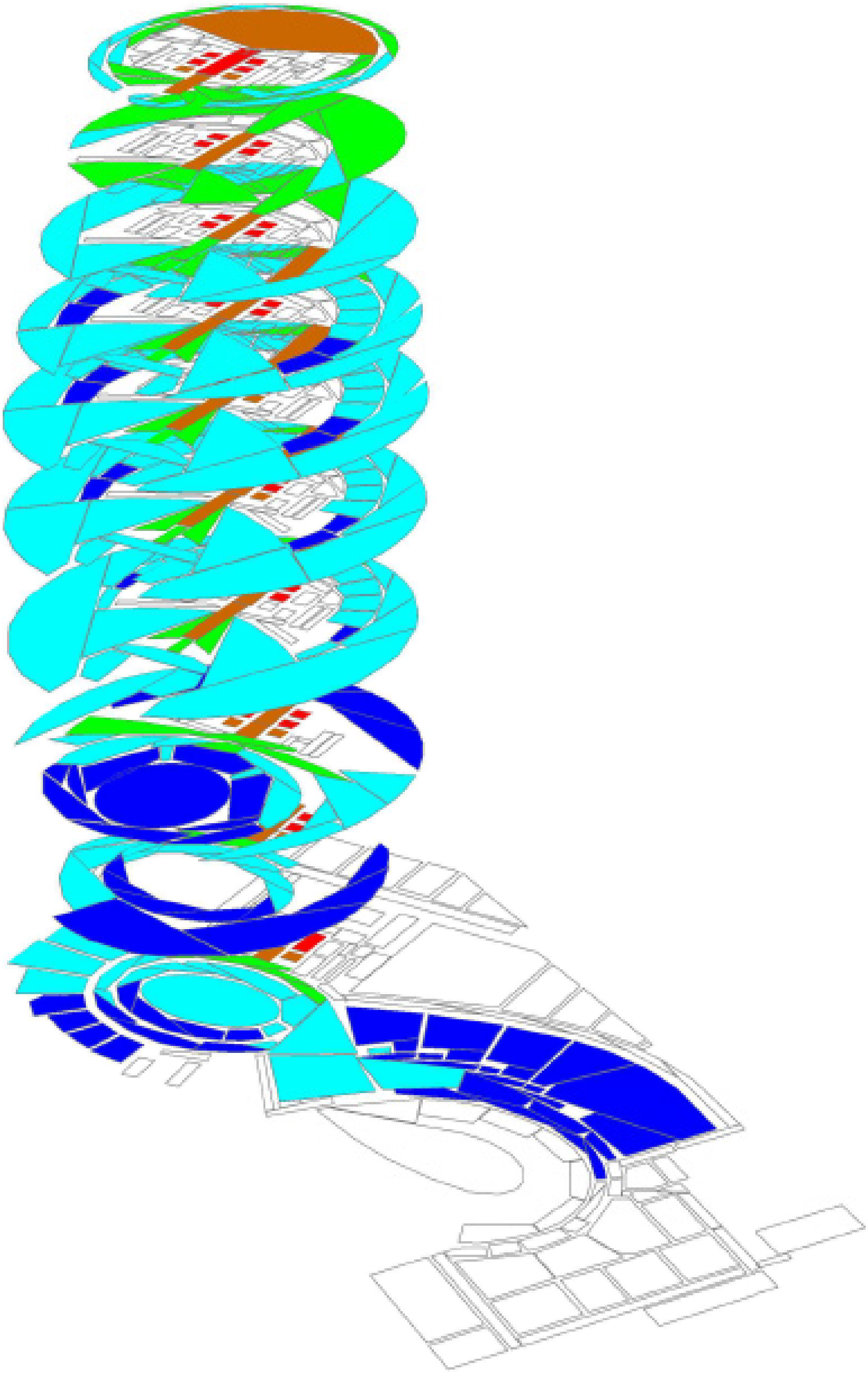


Figure 1.2. Angular choice in Manhattan. Source: Kinda Al_Sayed, 2007 @UCL.

CONVEX AND AXIAL ANALYSIS



THEORETICAL BACKGROUND ON AXIAL AND CONVEX ANALYSIS

Introduction

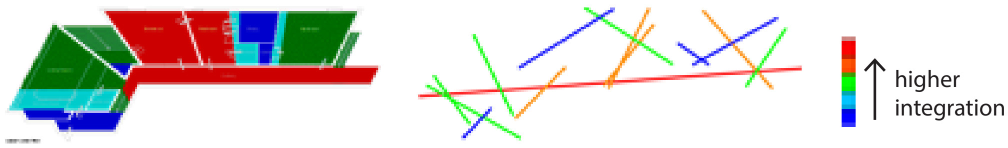
In this chapter, we will explain some basic topological graph representations of buildings and cities. Along with other software[2], UCL Depthmap has the capacity to produce different sorts of spatial analysis on different scales. Here, we are going to learn about axial and convex analysis, what it can do and how powerful it is as a tool for predicting social and economic activity, along with the different scales of measurement associated with it. We will also introduce integration and choice along with few other measures that will help understanding the social logic that space might afford and the link between spatial measures and the likelihood for movement and occupation in a layout.

[2] See wiki page on spatial network analysis software [http://en.wikipedia.org/wiki/Spatial_network_analysis_software]

Two representations of buildings and urban spaces

Space Syntax starts with defining movement and occupation as the fundamental functions of a layout, where permeability of all spaces is the priority condition for a functioning layout structure. A proposed representation of a spatial structure might either be interpreted in a convex map or an axial map[3]. An example for both types of representations is displayed in figure 2.1.

[3] See appendix 1 for a mathematical definition of the axial and convex network.



An analysed convex map

An analysed axial map

Figure 2.1. An example of how convex and axial representations are mapped on House at Creek Vean, Team 4. Source: Sarah Parsons, MSc AAS student work 2007 @UCL

1. A representational scheme of axial networks

On an urban scale, Space Syntax regards movement as the generic function of street spaces and hence; reduces these spaces to the longest accessible lines that cover all convex spaces in a map, that is; the axial lines or "lines of sight". These elementary components and their adjacency relationships can be represented by a network (nodes or vertices of a morphological graph G_A). The graph G_A will consist of two sets of information; graph vertices (representing axial lines) $V_A = \{v_{A1}, v_{A2}, \dots v_{An}\}$, and a set of lines $L_l = \{l_{l1}, l_{l2,} \dots l_{lL}\}$, each line in the graph G_A represents an intersection between two axial lines (two Vertices) in the spatial network. Spatial adjacency is the fundamental relationship that characterises how structures might be configured in a spatial layout. Two spaces, i and j, are considered as adjacent in the dual graph G_A when it is possible to access one space directly from another, without having to pass through intervening spaces. In graph-theoretic, G_A graphs is regarded as non-planar dual graphs. It is non-directional in that;
$l_k = (v_i, v_j) = (v_j, v_i)$

In axial representations, depth is identified as the change in direction between one axial line and another. Depth is topological, in other words, it has no geometric value. Axial maps are fundamental syntactic representations theoretically, because they reflect many structural properties of urban street networks– i.e. line lengths, intelligibility and synergy.

An example for how an urban area might be represented using the Space Syntax model is demonstrated in (figure 2.2.). The urban space (a.) might be represented by the set of fewest, longest, and walkable axial lines (b.), the axial lines are then represented by a graph (c.), the different Connectivity (degree) values for each vertix is then highlighted; vertices that have more connections to their immediate neighbours will have higher Connectivity values (d.), these values of Connectivity are then illuminated on the axial map to reveal the local network structure of street spaces (e.).

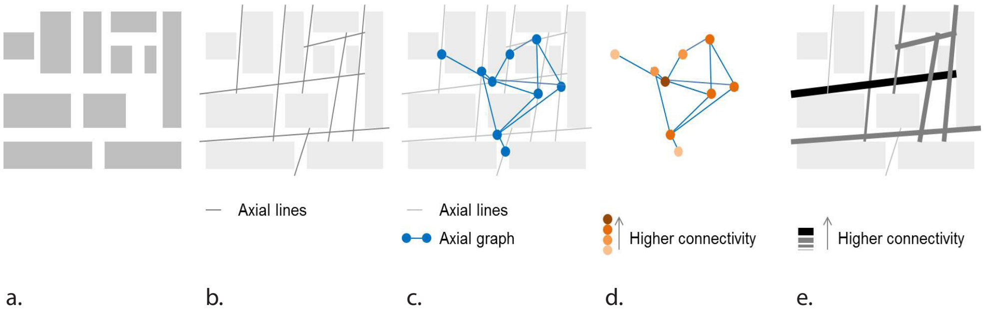


Figure 2.2 The axial representation of Space Syntax. An urban space represented by the fewest and longest axial lines (b), axial lines are represented by a graph (c), the graph Connectivity is by highlighted in (d & e).

2. A representational scheme of convex maps

Another syntactic representation of architectural space is that of convex map. A discrete convex map represents adjacency relationships by reducing the spatial complexity of a layout to the fewest and fattest convex spaces[4]. In each convex space, all pairs of points are inter-visible. Spaces that are immediately adjacent will have one step of depth in-between, spaces that have a minimum of one space separating them will have two steps of depth in-between, and so on. In other words, depth between two spaces is defined as the least number of syntactic steps –or shortest topological distance- in a graph that are needed to move from one space to the other.

[4] Note that this is only one possible representation of convex spaces (see Peponis et. al., 1997 for other alternative descriptions of convex break-up).

We can attribute the value of topological depth to each node (vertex) in an adjacency graph G_C. The graph G_C will consist of two sets of information; graph vertices (representing convex spaces) $V_C = \{v_{C1}, v_{C2}, \dots v_{Cn}\}$, and a set of lines $L_A = \{l_{A1}, l_{A2}, \dots lA_L\}$, each line in the graph G_C represents an adjacency relationship between one convex space and another. Spatial adjacency is the fundamental relationship that characterises how structures might be configured in a spatial layout. Two spaces, i and j, are considered as adjacent in the dual graph G_C when it is possible to access one space directly from another, without having to pass through intervening spaces. The mathematical description of the network representation of convex spaces is similar to that of axial networks.

Figure 2.3 shows an example for decoding an architectural layout designed by Frank Gehry using the convex space representation. The architectural space (a.) might be represented by the set of fewest and fattest convex spaces. These spaces are linked where there is direct access from one space to another forming a convex map (b.), the convex map is then represented by a graph (c.), the different Connectivity (degree) values for each vertix is then highlighted; vertices that have more connections to their immediate neighbours will have higher Connectivity values (d.), these values of Connectivity are then illuminated on the convex map to reveal the spatial structure of the building organisation (e.).

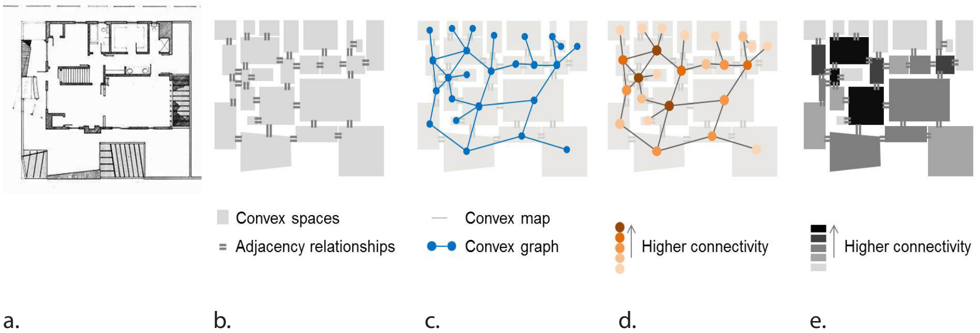


Figure 2.3 The convex representation of Space Syntax. An architectural space represented by the fewest and fattest convex spaces (b), convex spaces are represented by a graph (c), the graph Connectivity is by highlighted in (d & e).

Spatial relations between adjacent spaces in a layout can be represented using the descriptive methods of justified graphs[5] first presented by Hillier & Hanson (1984). A justified graph reads a spatial network of convex spaces from one space (root) to all others; representing each convex space with a circle and each permeable connection between two spaces with a line as in (figure 2.4). From a root space, all spaces that are one syntactic step away are put on the first level above the root space, all spaces that are two steps away are levelled on the second row, etc. A justified graph might be deep or shallow depending on the relationship of the root space to other spaces. Spatial relationships might form branching trees or looping rings. A spatial relationship between two spaces might be 'symmetrical' if for example: "A connects to B" is equal to "B connects to A". Otherwise the relationship is considered as 'asymmetrical'. The total amount of asymmetry in a plan from any point relates to its mean depth from that point, measured by its 'relative asymmetry' (RA). Spaces that are, in sum, spatially closest to all spaces (low RA) are the most integrated in a spatial network. They characteristically afford dense traffic through them due to their central position in the spatial network. Spaces that locate in deeper locations (high RA) are the most segregated. Integration and segregation are global attributes of the spatial network.

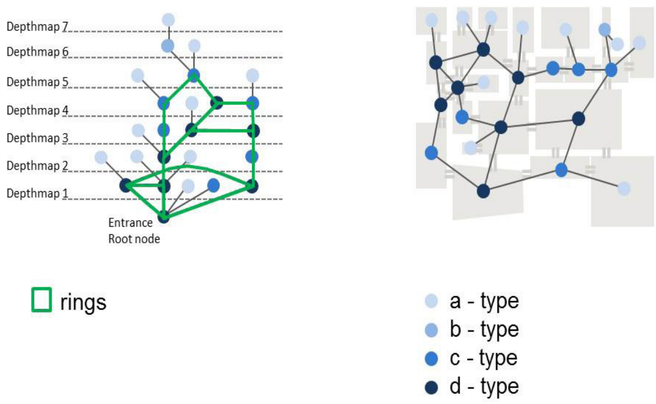
[5] A justified graph could be constructed using JASS or PAJEK tools.

Spatial layouts are often a combination of hierarchical structures and circulation rings. Normally the tree-like structure of space reflects a deep and controlled spatial structure and perhaps a hierarchy in the social organization that occupies a building. Conversely, the provision of interconnected rings of movement in a layout offers choices for movement routes reducing the depth of space. The spatial typology of each convex space is likely to differ depending on its relationship to movement rings (figure 2.4).

Hillier (1996) differentiated between four types of spaces:

- a-types; which are characterised as dead-end spaces and connect to no more than one space in a graph
- b-types connect to two or more spaces in a graph without being part of any ring of movement.
- c-types are usually positioned on one ring of movement.
- d-type of spaces must be in a joint location connecting two or more rings.

The positioning of a, b, c, d types of spaces within the local and global settings of the whole network can determine the overall spatial depth in a layout. A local increase in the number of a-type of spaces and a global increase in d-type of spaces would consequently minimise spatial depth, creating an integrated system, while a global increase of b-type spaces and a local increase in c-type spaces are likely to lead to a maximised depth, resulting in a segregated system.



a. b.

Figure 2.4 Different spatial typologies marked on a graph representing the relationships between convex spaces. The two graphs elucidated here are; a justified graph that is being laid from the point connecting the exteria to the interia of Frank Gehry's house (a.) and an adjacency graph overlaid on top of a convex map (b.).

It is possible to apply the representational scheme of justified graphs to both axial and convex graphs. The ringiness of axial graphs is crucial to distinguish patterns of order and structure in street networks, For the purpose of quantifying these properties, a measure of axiality in the axial graph was proposed in (Hillier & Hanson, 1984:91); that is the ratio of circuits/rings in the axial graph to the number of axial lines. Grid axiality might follow the following formula;

$$\text{Grid axiality} = \frac{(\sqrt{I} * 2) + 2}{L}$$

where I is the number of islands, L is the number of axial lines. The results vary between 0 and 1 with high values approximating to a regular grid and low values to an axialy deformed system.

Syntactic measures

In this section we will be explaining four main topological measures that can explain structural properties of a spatial graph. The measures are used to quantify the configurational properties of a layout. The calculation might account for the neighbourhood size of each node in a graph. By neighbourhood we mean the nodes that are linked to each node within a certain graph distance that might either be topological, metric or angular. For axial and convex analysis we use a topological distance that is calculated from each node to define the radius within which different measures are calculated. Radius n is usually used to find measure values for each node in relation to the whole system. Radius 2 (sometimes called radius 3), is used to measure the relationship between each node and the neighbours located two steps away from it.

During the last four decades, Space Syntax researchers have developed many measures (see appendix 1) for the purpose of explaining social behaviour, some of the most important ones are listed here;

> Connectivity (degree) measures the number of immediate neighbours that are directly connected to a space.
>
> Integration is a measure that describes relativized asymmetry in the graph network. It is a measure of mean depth that is specifically adapted for architectural layouts. The global measure shows how deep or shallow a space is in relation to all other spaces. Using integration, spaces are ranked from the most integrated to the most segregated. Integration is usually indicative to how many people are likely to be in a space, and is thought to correspond to rates of social encounter and retail activities (Hillier, 1996a). It is sometimes helpful to illuminate higher values in a system (i.e. the highest 10% values) in order to illuminate the integration core in a city. The integration core might take different shapes (a spine, a deformed wheel, diffused, and concentrated).
>
> Control measures the degree to which a space controls access to its immediate neighbours taking into account the number of alternative connections that each of these neighbours has.
>
> Choice measures movement flows through spaces. Spaces that record high global choice are located on the shortest paths from all origins to all destinations. Choice is a powerful measure at forecasting pedestrian and vehicular movement potentials. It is usually applied to segment analysis rather than convex analysis, because it is descriptive of movement rather than occupation.

The correlation between some of these measures might describe some characteristic properties of layouts that relate to wayfinding (Conroy Dalton, 2000). Intelligibility, for example, is the correlation coefficient between axial connectivity and axial global integration. It helps identify how easy it is for one in a local position to comprehend the global structure. Synergy is the relationship between smaller radii of integration (i.e. integration HH R2) and larger radii (i.e. integration HH Rn) - also in axial analysis. A relationship between smaller and larger radii is illustrative of the relation between the parts and the whole in an urban system.

DEPTHMAP EXERCISE
Axial and Convex Analysis Using Depthmap

Files available for you to use in the exercise

FILES	DESCRIPTION	SOURCE	COPYRIGHTS
GALLERY.DXF	Cad drawing file containing an architectural layout	https://github.com/SpaceGroupUCL/Depthmap/wiki/Depthmap-Tutorials	The original CAD data copyright © Cambridge University Press 1984, reproduced here with kind permission. Original drawings by J Hanson, digitised by A Turner.
GALLERY _convex.dxf	Cad drawing file containing a convex break-up map	http://moodle.ucl.ac.uk/	
GALLERY _axial.dxf	Cad drawing file containing intersecting series of line elements		

TASKS

The first task is to reduce an architectural layout into a convex map and analyse its graph properties using Depthmap.
The second task in this exercise is to reduce an urban layout to an axial map and analyse its topological configurations.

Before you start

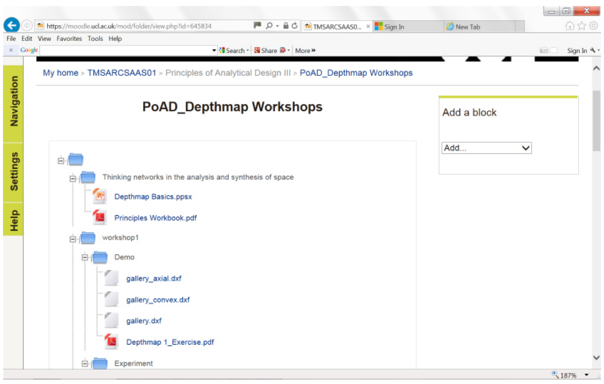
- Download Depthmap 10.14 from https://github.com/Space-GroupUCL/Depthmap/downloads

- Note that Depthmap only runs on the Windows operating system. If you have a Mac, you can use DepthmapX.

TASK 1: STEPS TO PERFORM CONVEX ANALYSIS IN DEPTHMAP

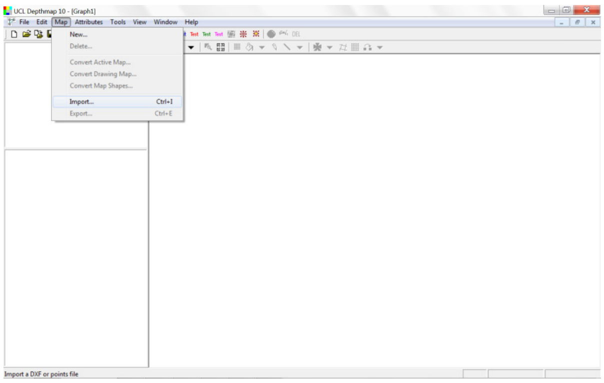
In this exercise you will learn to do the following activities in Depthmap in order to draw convex break up maps manually and perform convex analysis.

- 1. Download your files



Go to Moodle and download the file GALLERY.dxf from the website onto your desktop

2. Prepare your convex map



Create a new file: Go to FILE---NEW. This gives a blank page.

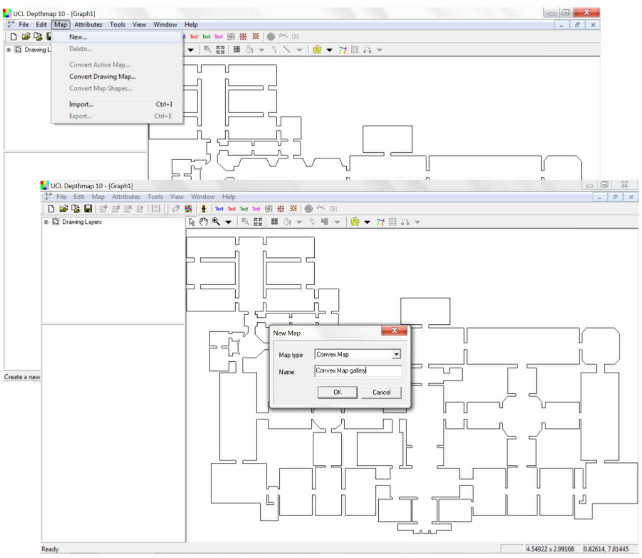
Save the file you are using as "GALLERY_ convex_axial.graph": FILE---SAVE

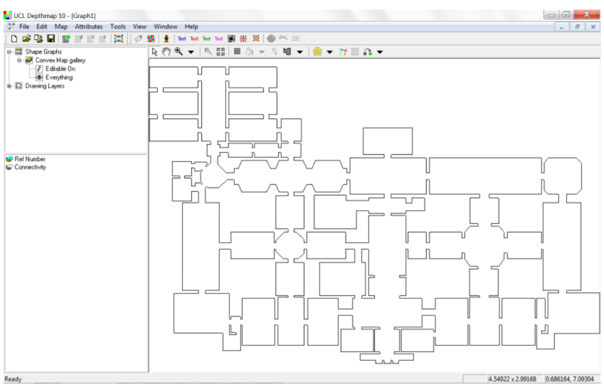
Choose the name and location of your file

Import the architectural layout into Depthmap: go to MAP--- IMPORT--- look in your Desktop for a file titled GALLERY.dxf. Choose the DXF file and click import. Now you will have the file imported into your Depthmap file as a drawing layer[6].

[6]Note that the layout is carefully drawn in such a way as to not leave gaps within the boundaries of the street structure. This is important for automatic generation of the axial lines.

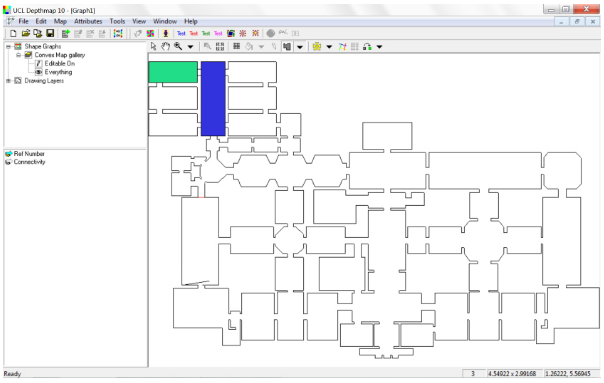
3. Draw and connect convex spaces



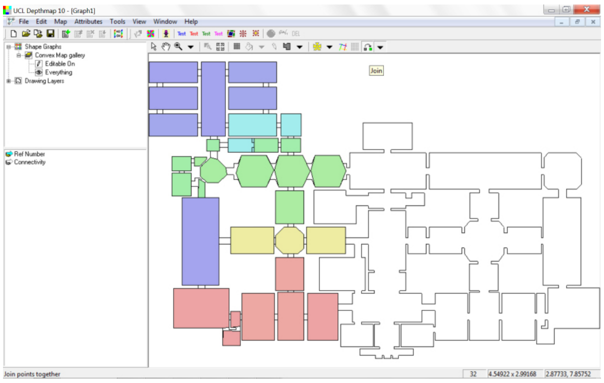


Set up a new layer to draw your convex spaces. You can do that by going to MAP→NEW... and a NEW MAP window will appear where you can choose what kind of map you are intending to establish.
Choose CONVEX MAP from the MAP TYPE drop down menu and give your convex map a unique name.

After clicking OK you will have your new convex map layer on the left within a category called shape graphs.
Once you have checked the + button next to it you will be able to see the layer is set to be editable by default and this means that you can draw polygons on the screen and the polygons will be recorded as separate elements within this layer.
The term EVERYTHING that you see next to the eye icon means that you can see all the convex spaces you have drawn on the screen.
At the moment you have nothing drawn in that layer but once you have completed more than one polygon you will see these polygons assigned different colours if you are pointing to the reference number.

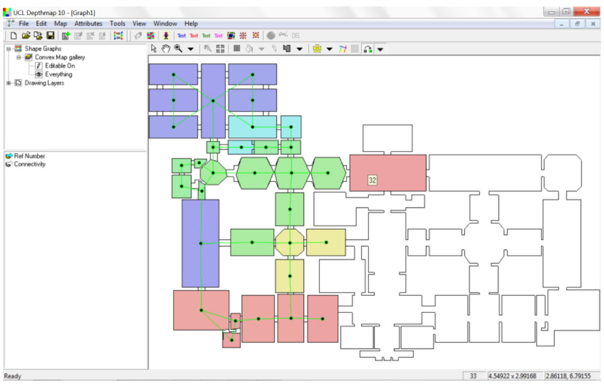


In order to draw the convex spaces you will have to check the polygon icon on top of your MAP window . Then you can draw the convex spaces by clicking with your left mouse key to identify every single point that defines the boundary of the convex space and close the polygon by clicking on the starting point. Meanwhile, you can snap the end points to the layout by holding CTRL+SHIFT while you are drawing.
You can cancel your polygon while you are drawing it by clicking the right hand mouse button.

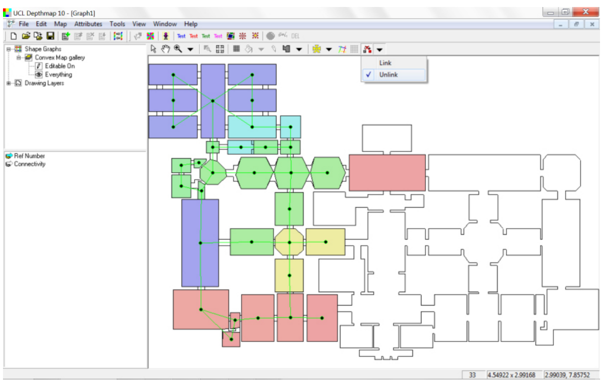


For drawing convex spaces you will have to follow the fewest and fattest rule in which the fewest prevail over the fattest[7]. The minimum convex space would contain a space for two people within. The grid scale of it would be equivalent to 1.2 metres if the original CAD layout is set to a metric scale.

[7] Decisions may vary in relation to defining a convex space. You can reason about your decisions based on the change in space functionality or usage.

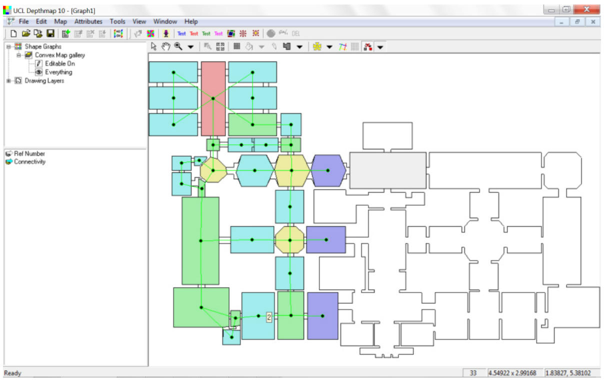


Once you have done your convex breakup map, you have to connect your convex spaces to create a graph out of them. You can do that by clicking the join icon in your tool bar and linking spaces where accessible openings and doorways exist in-between. Just select one polygon (convex space) and select the polygon it links to and you will see an edge linking the centres of both polygons. After you have linked all spaces in your convex map you will be able to analyse convex relationships that are based on the adjacency criteria.



In case you have done some mistakes in the linking process, you can unlink convex spaces by choosing the unlink icon from the drop down menu next to the join tool and unlink where necessary.
For linking again you need to go back to the join icon and click on it to activate it. You can skip this mode by clicking the select icon .

On the lower left part you will be able to see the set of measures you have analysed so far. For every convex space you have drawn on the screen you will have a unique reference number assigned to it automatically (the



colours do not mean anything at this stage). For every convex space you will also have a connectivity attribute;

- Connectivity indicates the number of elements each element is directly connected to. After you have linked your convex map all together, the colours of connectivity indicate in which band the value of the convex space falls within the range of spaces drawn on the screen.

This attribute will not be calculated until you start linking the convex spaces together. The element that is not yet connected to the network will be in gray colour. If you point to one of the connected polygons on the screen you will be able to see its connectivity value. The one that is not connected will show 'no value'.

You can undo recently drawn convex spaces by going to EDIT→ UNDO or you can use the shortcut CTRL+Z. You can also delete polygons but be careful though! Save your file before you do that as this very often resolve with an error. To delete polygons, you need to click the selection icon and select the polygon that you want to delete. The elements you select will be highlighted with bright yellow colour. Click the delete button on your keyboard or go to EDIT→ CLEAR.

Do you feel that your convex map is precisely drawn? You are now advised to turn off the editable on option by clicking on it. You can do that after you have finished drawing you convex map to avoid accidental editing of your convex map elements. Please remember to save your file before you move to the analysis stage.

4. Import your convex break-up map from a drawing file

If you have failed to produce a convex map in your Depthmap file for any reason, don't worry there is a convex map prepared for you in a DXF file. Just go to Map→ IMPORT and import a DXF file called GALLERY-convex.DXF from the Depthmap folder in Moodle. You will find that in the samples folder within exercise 1. You will have it imported as a drawing map.

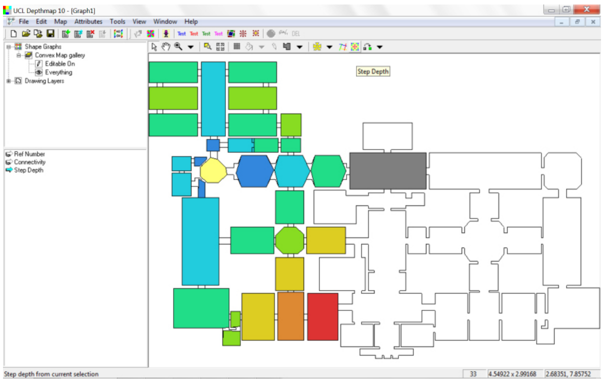
Go to MAP→ CONVERT DRAWING MAP and

select NEW MAP TYPE to be CONVEX MAP. The default name is CONVEX MAP. Give your convex break-up map a unique name.

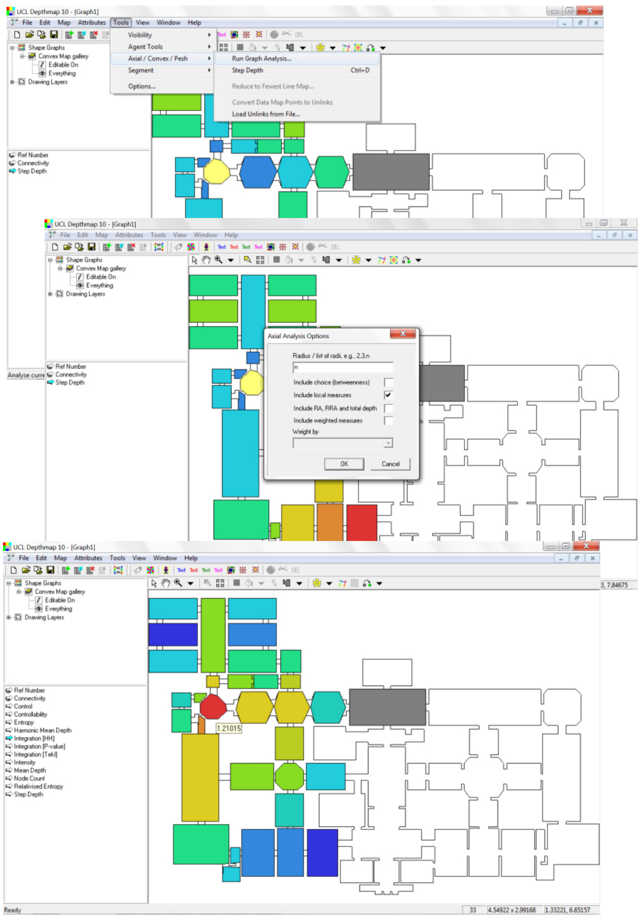
Start linking your convex spaces together as explained in the previous section

Once you have got all your convex spaces linked together in a convex map, you will be able to see the basic attributes of the convex map, which are; REFERENCE NUMBER, CONNECTIVITY in the lower left corner of your screen.

5. Convex analysis



At the moment, the only analytical operation you can perform with the convex maps you have is to calculate step depth (topological). You can do that by selecting one convex space and clicking on the step depth icon in your tool bar . You will need to invert the colour range by choosing the icon specified for it on the main tool bar . The blue colour will represent then the deepest element from the selected convex spaces in the adjacency graph network.

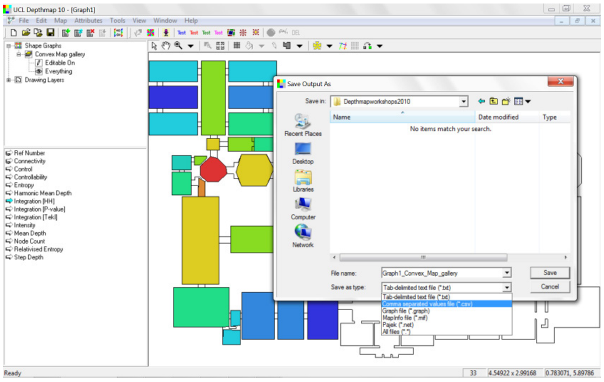


If you need to check further local and global measures, you will have to go to TOOLS→ AXIAL/CONVEX/PESH→RUN GRAPH ANALYSIS. A window will appear where you could select your convex analysis options. In the window, leave everything as it is and just make sure to check the boxes next to INCLUDE LOCAL MEASURES.

After you click OK you will see different measures added on the lower left corner of your screen. The most meaningful measure[8] is INTEGRATION (HH).

[8] Additionally, CONTROL and CONTROLLABILITY measures can be of interest but may be more indicative in VGA than in convex analysis.

- Integration is representative of potentially core functionality in the layout. Integrated spaces are highlighted as red and appear in the shallowest areas of the graph. Segregated spaces fall within the range of blue. Integration and segregation are suggestive of parallel social meaning in the built form.



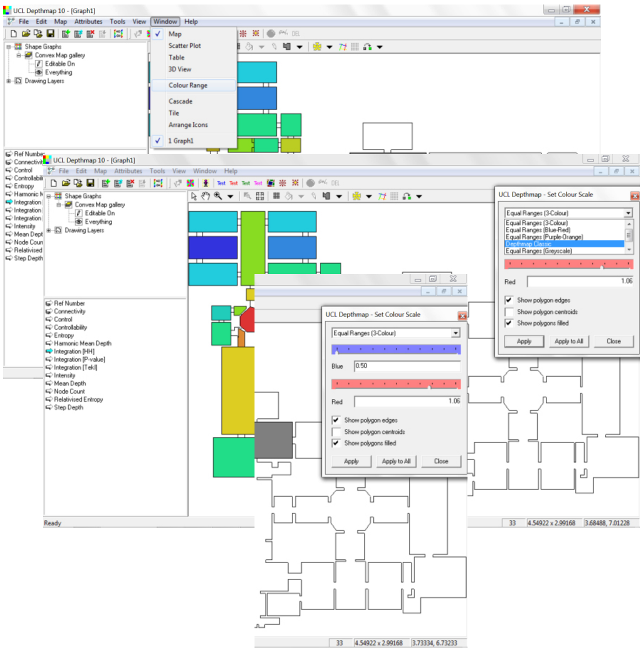
Segregation in the architectural layout might be an indication to a higher degree of power or a lower degree of power depending upon the social organisation that occupies that space (i. e. Head office, prisoners).

Now that you are done with convex map analysis, please remember to save your file.

You can also export your convex graph as a Pajek file. You will be able to use this Pajek file for further exploration into topological graph measures and for the purpose of producing justified graphs.

6. Changing your colour range

In order to read differences more clearly between high low values of each measure you can change the colour range. This is just for the purpose of data visualisation and will have no effects on the values of elements themselves.



Go to WINDOW---COLOUR RANGE.
A window will appear.
Use the browser to move to Depthmap classic as a banding range type.
Adjust the sliders in such a way as to find a satisfactory representation of the data values in the axial or convex map.

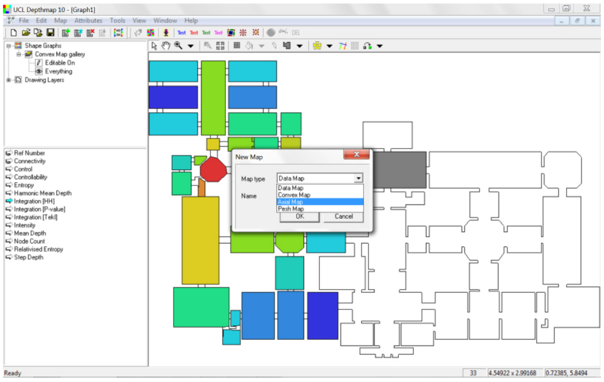
Please bear in mind that when comparing different systems you need to unify the ranges by setting the same min and max limits.

TASK 2: STEPS TO PERFORM AXIAL ANALYSIS IN DEPTHMAP

In this exercise you will learn to do the following activities in Depthmap in order to perform axial analysis from axial lines you have drawn or automatically generated.

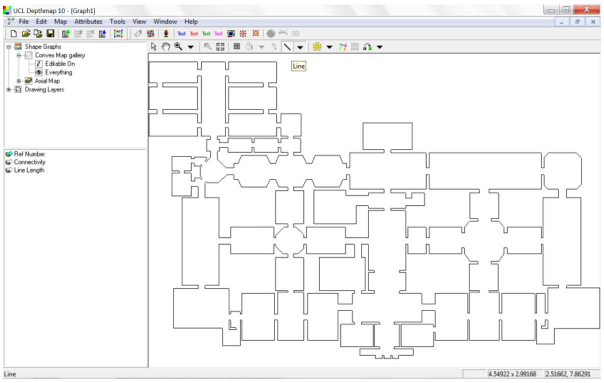
7. Draw your axial lines

Set up a new layer to draw your axial lines. You can do that by going to MAP→ NEW... and a NEW MAP window will appear where you can choose what kind of map you are intending to establish. Choose AXIAL MAP from the MAP



TYPE drop down menu and give your axial map a unique name.

After clicking OK you will have your new axial map layer on the left within a category called shape graphs. Once you have checked the + button next to it you will be able to see the layer is set to be editable by default and this means that you can draw lines on the screen and the lines will be recorded in this layer. The term EVERYTHING that you see next to the eye icon means that you can see all the lines you have drawn on the screen.

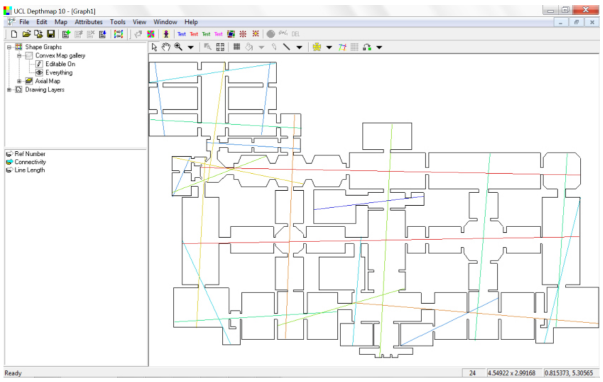


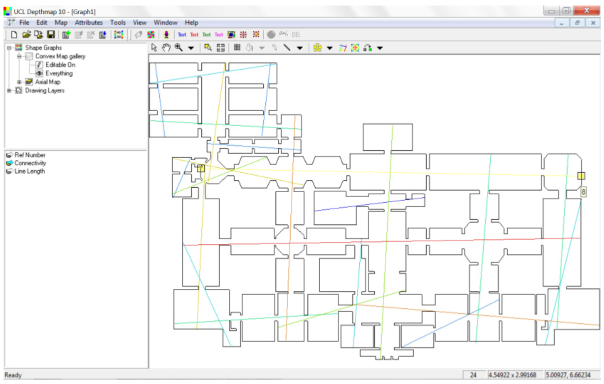
In order to draw lines you will have to check the line icon on top of your MAP window. Then you can draw the lines by clicking with your left mouse key and dragging until you reach the second point of the line.

Draw axial lines on the layout by following the rule the fewest and longest axial lines that would cover all convex spaces in the system, the fewest to prevail. One tip is to start by drawing the longest lines and then the shorter ones until you cover all the permeable spaces in the layout. Always try to get the axial lines to intersect where possible. Where lines are considered to be nodes in the axial graph network, Intersections between lines are the links that connect these nodes. Having missed an intersection between two lines means necessarily further depth between the two lines is to be considered in the calculations. This will have implications over the overall graph network. Draw the lines diagonally across the street spaces, and lines that are likely to extend further to cover other street spaces are more preferred[9]. During the process of drawing you can turn on the object snapping by pressing CTRL + SHIFT will trying to find end points or mid points on your layout.

[9] In cases where you are conducting observations in certain urban areas you are encouraged to check the real urban or architectural set up and adjust your axial map accordingly.

On the lower left part you will be able to see the set of measures you have analysed so far. For every line you have drawn on the screen you will have a unique reference number assigned to it automatically (the colours do not mean anything at this stage).
For every line you will also have connectivity



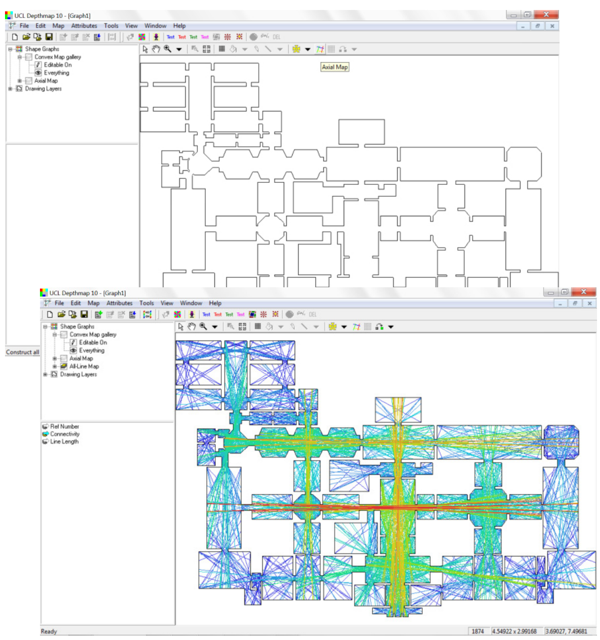


and line length calculated for it immediately after you have drawn it (The colours indicate in which band the value of the line falls within the range on lines drawn on the screen).

If you feel that you have done some mistakes don't worry you can always edit your lines. You can undo recently drawn lines by going to EDIT→ UNDO or you can use the shortcut CTRL +Z. You can also delete lines but be careful though to save your file before you do that as this very often resolve with an error. To delete lines, you need to click the selection icon and select the line that you want to delete and click the delete button on your keyboard or go to EDIT→ CLEAR. Try to avoid deleting lines; instead, you can edit certain lines to fit other spaces by clicking on the selection tool and selecting a line on the screen. You will then be able to see the handles on each line you select. Just move the handles to any direction you want using your left mouse key (click, drag and drop).

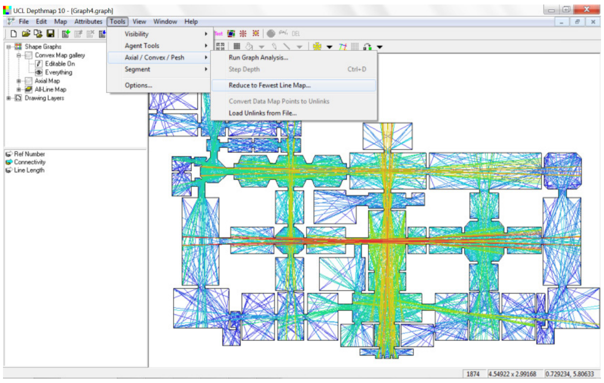
Do you feel that your axial map is precisely drawn? You are now advised to turn off the editable on option by clicking on it. You can do that after you have finished drawing you axial lines to avoid accidental editing of your axial map elements. Please remember to save your file before you move to the analysis stage.

8. Generate your axial lines automatically

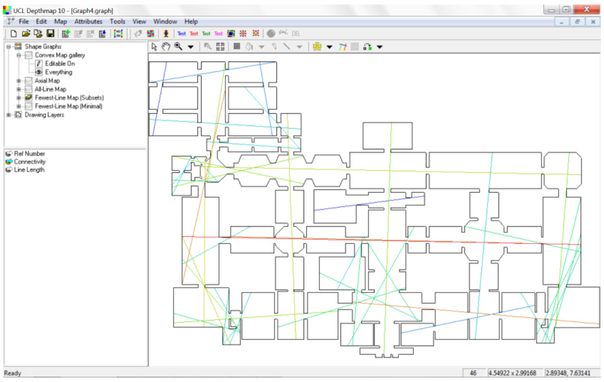


As an alternative to the manual drawing of axial lines you can generate your axial map automatically from your drawing file.
To do that you should have the drawing layout precisely drawn and make sure that you have no gaps left in the boundaries that enclose your spaces.

First you need to create an ALL-LINE MAP by clicking on the icon where four axial lines appear in your tool box. After doing that a dropper type of cursor will appear with which you will point to the inner space of your architectural layout and you will see an all-line map generated within that boundary. At the moment the map looks too dense and covering most of the areas in the spaces. Individual lines can hardly be distinguished at this stage. The measures of connectivity and line length are already attributed to this map.

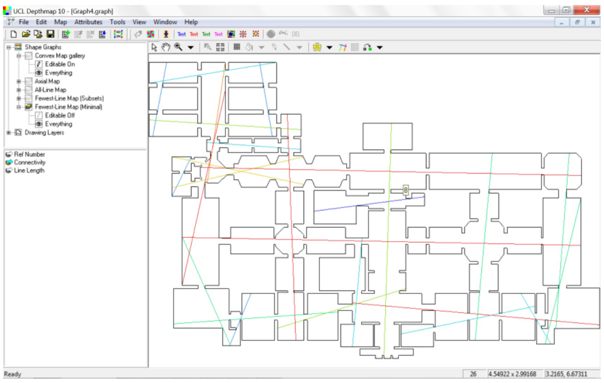


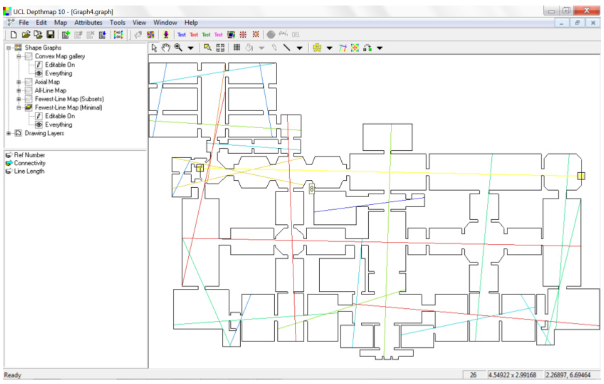
In order to reduce this map to the fewest lines you need to go to TOOLS→ AXIAL/CONVEX/PESH→ REDUCE TO FEWEST LINE MAP.



You will be able to see two types of reduced axial maps. The SUBSETS map is more representative of curvy spaces.
The MINIMAL is the fewest-line map you normally use.

It is recognised that in the absence of correct base drawings, this might be more difficult and time consuming than drawing an axial map manually.





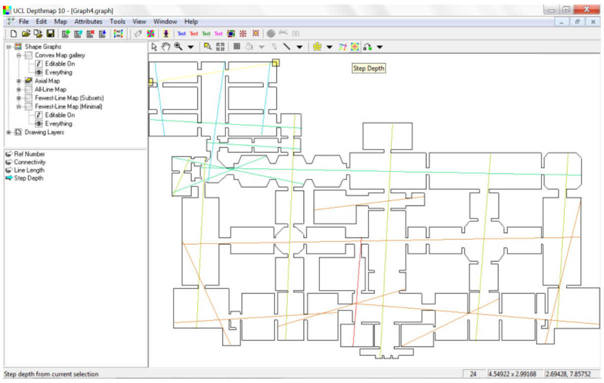
You might disagree with the solution provided by the process of automatic reduction of all line maps. In this case, it is important to note that the automatic generation of axial lines does not always resolve with the fewest map. There is an acceptable margin of error in the calculation especially with instances where you have curvy patterns of street structures. You can always turn editable on and edit the lines yourself.

9. Import your axial map from a drawing file

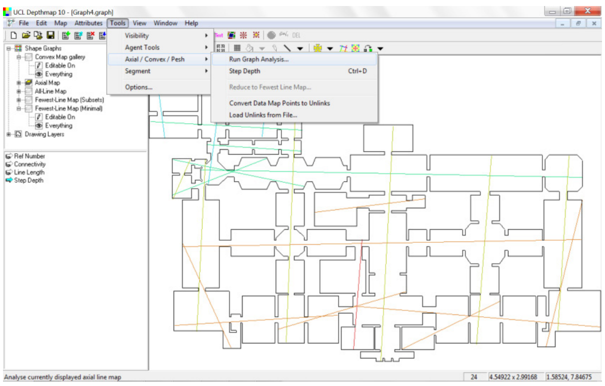
If you have failed to produce axial maps in your Depthmap file for any reason, don't worry there is an axial map prepared for you in a DXF file. Just go to Map→ IMPORT and import a DXF file called GALLERY-axial.dxf from the Depth-map workshop's Moodle Folder. You will find that in the samples folder within exercise 1. You will have it imported as a drawing map.

Go to MAP→ CONVERT DRAWING MAP and select NEW MAP TYPE to be AXIAL MAP. The default is AXIAL MAP and it will number it if you have more than one axial map. Name your AXIAL MAP to avoid confusion between numbers. You will be able to see the basic attributes of an axial map, which are; REFERENCE NUMBER, CONNECTIVITY, LINE LENGTH in the lower left corner of your screen.

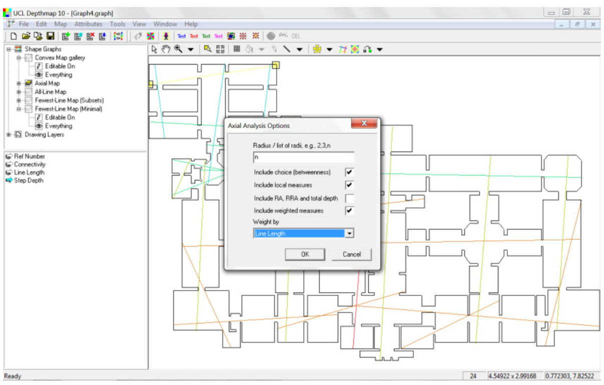
10. Axial analysis

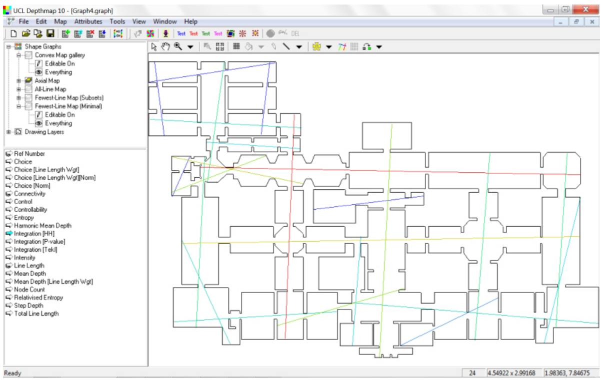


At the moment, the only analytical operation you can perform with both the manually and automatically drawn axial maps is to calculate step depth (topological). You can do that by selecting one axial line and clicking on the step depth icon in your tool bar . You will need to invert the colour range by choosing the icon specified for it on the main tool bar . The blue colour will represent then the deepest element from the selected axial lines in the axial graph network.



If you need to check further local and global measures, you will have to go to TOOLS→ AXIAL/CONVEX/PESH→RUN GRAPH ANALYSIS. A window will appear where you could select your axial analysis options. You can select a local topological radius to be added to the radius you already have in there (Radius n) by typing (n, 2, 3, 5, 7). The larger radii you choose the closer you get to radius n, depending on the node count (number of elements) you have in the system. Radius 2 stands for two steps away from each element; radius 5 means five steps away...etc. A step means a change in directional turns from each element in the system. Normally we use radius 2 for calculating local depth within walkable urban regions. Radii 5 & 7 are more likely to be used to observe vehicular movement on a global level. In the window, make sure you check the boxes next to INCLUDE CHOICE (BETWEENESS) and next to INCLUDE LOCAL MEASURES. You can also INCLUDE WEIGHTED MEASURES if you feel that any certain properties of the system can be revealed by building a relationship between two different measures.





After you click OK you will see different measures added on the lower left corner of your screen. The most meaningful in the first instance are INTEGRATION (HH) and CONNECTIVITY.

- Integration is representative of potential destinations in the system. These destinations are highlighted as red and appear in the shallowest areas of the graph. Segregated spaces fall within the range of blue. Integration and segregation are suggestive of parallel social meaning in the built form. In many cases integrated areas turn out to be active economic centres whereas segregated areas are associated with poverty and crime. However, it is important to note that these associations are too complex and case-sensitive to be generalised in simple terms.

- The rest of the measures are still under experimentation hence their observed meaning is yet to be proven and goes beyond our scope here.

Save your file

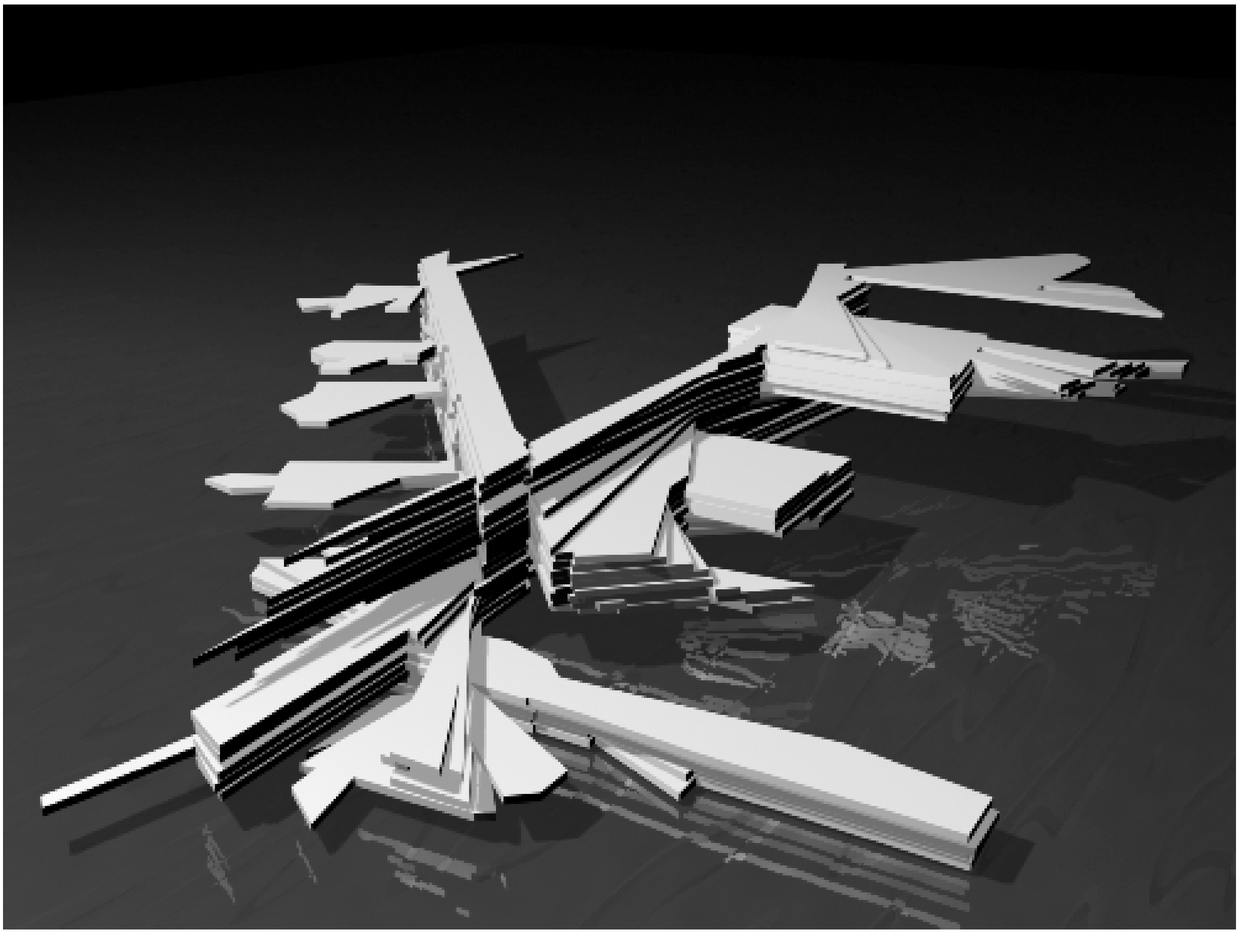
Notes

As per usual, try to follow the rules from the Social Logic of Space to draw each axial line. However, if you are more adventurous, you may want to think a little more about how to draw the axial map. See Turner et al. (2005) and in particular section 4.1 for a discussion of the role of depth minimization.

Always check the integrity of your axial map before piling straight into the analysis of your axial map, but wait! Check that your axial lines are properly connected to each other. You can go through the map looking at the number of connections (just hover the mouse over a line), or check all lines are connected by performing a 'step depth' calculation. Both of these methods can be found in the Depthmap axial analysis tutorial on the UCL Bartlett website.

Similar to what we have done with convex spaces linking/unlinking, you may need to unlink lines where it is not possible to get from road to another – for example, if there is a bridge. Go through the axial analysis tutorial to find out how to unlink lines, and unlink where necessary.

ISOVIST AND VGA ANALYSIS



THEORETICAL BACKGROUND ON ISOVIST AND VGA ANALYSIS

Introduction

In this chapter, we will present another type of representation that has to do with the visual properties of a layout, that is the inter-visibility between each pair of points in a layout and how that build into the visual configurations of the built environment. This finer grained representation is particularly important to address issues related to spatial cognition from a situated position. An understanding of the visual perception of the built environment might help forecasting how accessible spaces afford movement. This static representation makes the ground for the dynamic agent model that will be introduced in the final chapter.

Isovist and VGA analysis

An isovist, or viewshed, first introduced by Benedikt (1979), is the area in a spatial environment directly visible from a point (see figure 4.1). An isovist is a physical body bound by a closed polygon; hence it has geometric properties such as area and length of perimeter. The spatial properties of the visibility field can be attributed to that point and a graph can be constructed linking this point with other points. Isovists can also be constructed from an area (such as a convex space) to display the field visible from that area. In addition, isovists can be constructed from a façade, to illuminate the part of the environment that is visible from the façade surface. A set of isovists can also be constructed from a path at regular intervals to show how a user experiences space walking through the layout from a point of origin (i.e. entrance) to a certain destination (i. e. the deepest convex space). The set of isovists that cover this path are usually referred to as the Minkowski model (see figure 4.2).

To reproduce a representation that is similar to that of Hillier and Hanson (1984), Turner et. al. (2001) have constructed an undirected graph connecting all the inter-visible points in a human-scale grid. The product of this representation is a visibility graph where each point is notated as a node and inter-visibility is the condition for linking one node to the other. The visual relationships between different nodes in the system can be calculated using different local and global measures in Depthmap. The programme enables the application of visibility graph analysis on spatial layouts on different storey levels through the join tool.

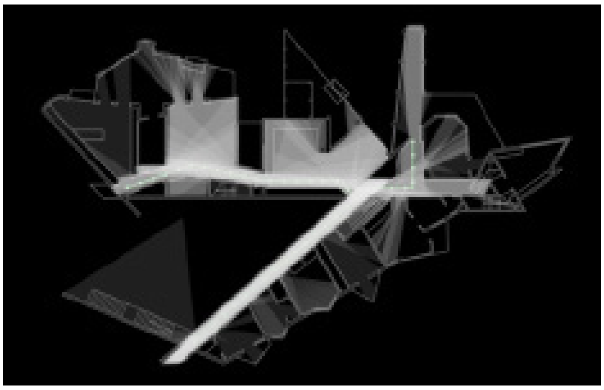


Figure 4.1. An isovist field for the corridor space in Maggie Edmond & Peter Corrigan Athan House 1989. Source: MSc AAS student work 2007 @UCL

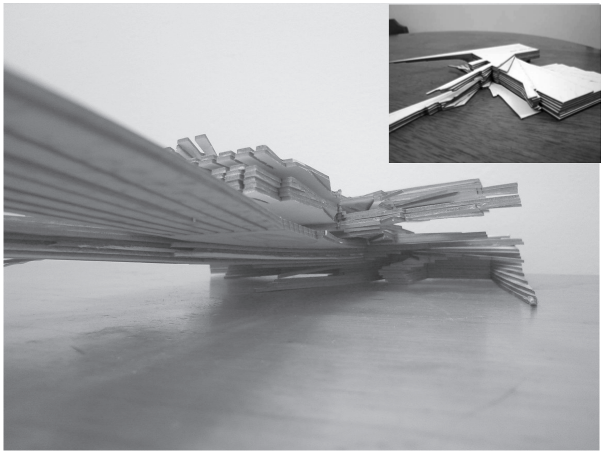


Figure 4.2. A Minkowski model for Frank Gehry house. Source: MSc AAS student work 2007 @UCL

Visibility graph measures

In this section, we will be explaining three main topological measures for visibility graph that explain a high resolution picture of the spatial configurations of a layout. The measures depend on the neighbourhood size. We will explain here the local measure of clustering coefficient, the global measure of integration and the local measure of control.

Clustering coefficient is derived from the local configurations of each node and calculates the degree to which nodes that are visible from one location are themselves inter-visible. Clustering coefficient is indicative to how much one loses in terms of visual information when moving from one location to another. Isovists that are closer to convex retain high clustering coefficient, hence little visual information is lost when moving from these locations. Contrary to convex isovists, spiky ones correspond to low clustering coefficient; hence more visual information is lost when moving away from these locations. Understanding these properties is vital for illuminating the relationship between navigation and wayfinding types of movement and how visual information changes in the system. For example, spaces that have low correlation coefficient tend to correspond to locations where pedestrians make decisions on directions. The clustering coefficient might be representative of convexity in a layout, by illuminating how 'self-contained' visual information is in an isovist field. The measure also exposes how disruptive certain objects are to the visual perception of a layout.

Integration is regarded as a global graph measure that computes the mean shortest path length for all the nodes in the graph. The shortest path in a graph is the least number of links or steps that need to be traversed to reach one node from another. The mean shortest path length for a node is the average value of all the shortest path lengths from this node to all other nodes. No normalised real relative asymmetry is considered here, since this measure is only used to compare location to location within a spatial setting.

Control calculates the area of the current neighbourhood with respect to the total area of the immediately adjoining neighbourhood. Control is useful for highlighting areas where observers can have a large view of the spatial layout.

DEPTHMAP EXERCISE
Isovist and VGA Analysis Using Depthmap

Files available for you to use in the exercise

FILES	DESCRIPTION	SOURCE	COPYRIGHTS
Gallery-convex _axial.graph	Depthmap file containing analysed architectural layout	File saved from last exercise	The original CAD data copyright © Cambridge University Press 1984, reproduced here with kind permission. Original drawings by J Hanson, digitised by A Turner.

TASK

The task is to produce isovist and visibility graph analysis VGA to analyse the visual configurations of the layouts.

STEPS TO PERFORM ISOVIST and VGA ANALYSIS IN DEPTHMAP

In this exercise you will learn to do the following activities in Depthmap in order to perform isovist and VGA analysis.

1. Download your files

Ideally, what is required for analysis is a closed polygon for the envelope of the building, complete with open doorways within the building. As an example for that we will use the plan of the National GALLERY that we used for the first Depthmap workshop.

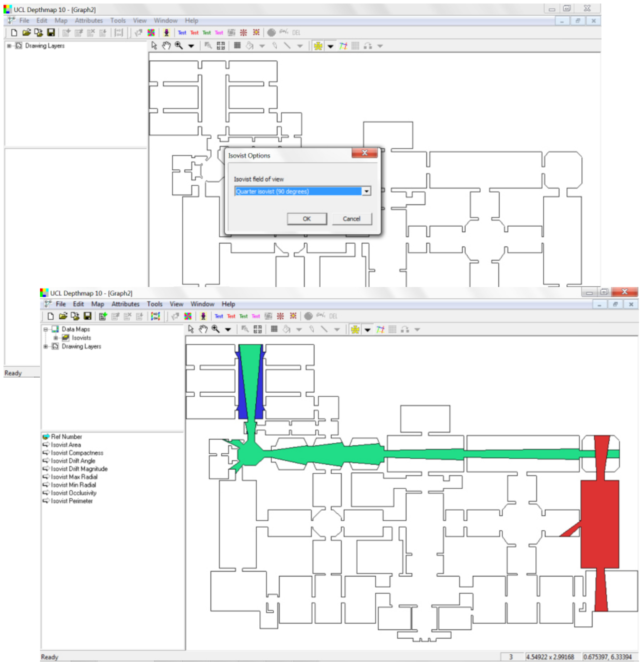
2. Prepare your file for isovist and VGA analysis

Open the Depthmap file you have done in the last workshop and use save as to create a new version of the file on which you will add the layer of isovists and visibility graph analysis.

Choose the name as "GALLERY_vga.graph" and location of your file

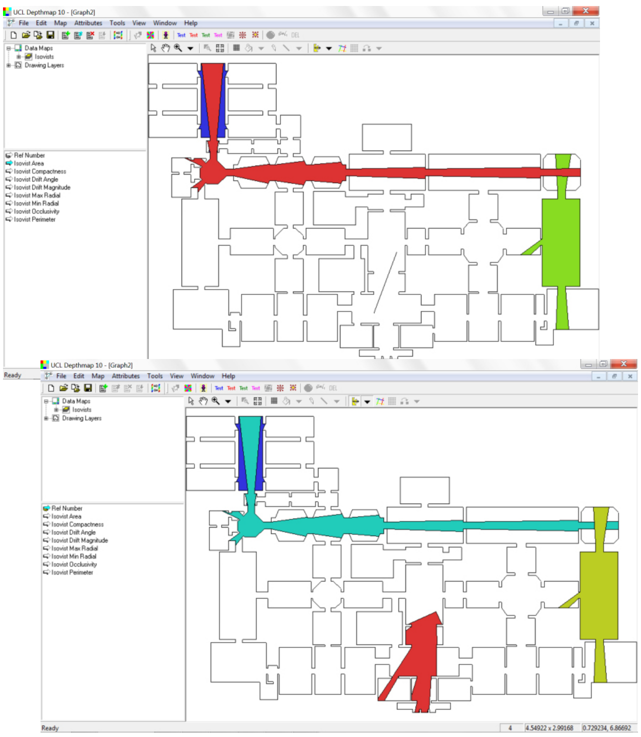
3. Create isovists

Click the button that symbolises an isovist in your tool bar  and press the left-hand mouse key once the eye-dropper tool is within the boundary of the layout. A window will appear on your screen offering you several options.



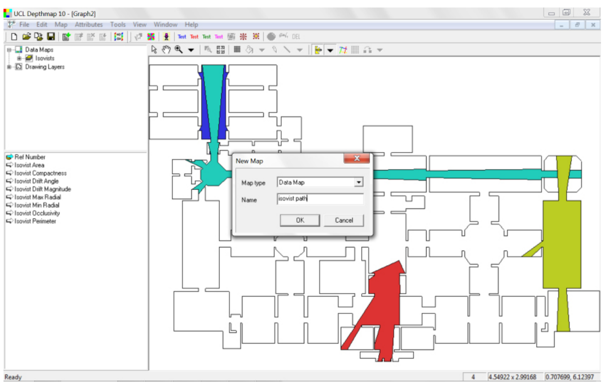
You can choose to have; quarter an isovist, third isovist, half isovist and full isovist.
You can choose one of these options and an isovist is going to be created at the point you have located.

At the moment choosing one of these options won't make any difference on your isovists. You will be able to see directly several isovist properties on your lower left hand side of the screen. Two of these properties are based on the geometry of the isovists such as area and perimeter; others are built on Benedikt's measures.

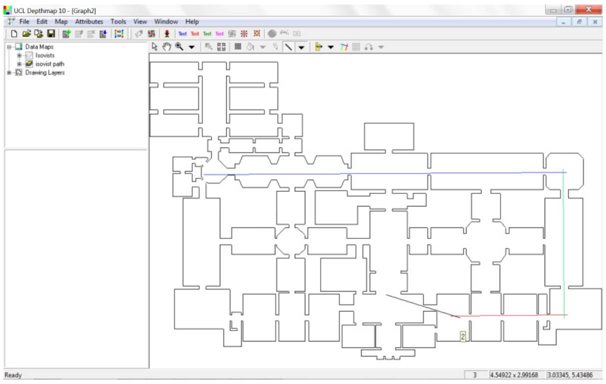


You can also choose the partial isovist tool  ; for which you will need to define with eye dropper tool a point of origin for the isovist and a direction.

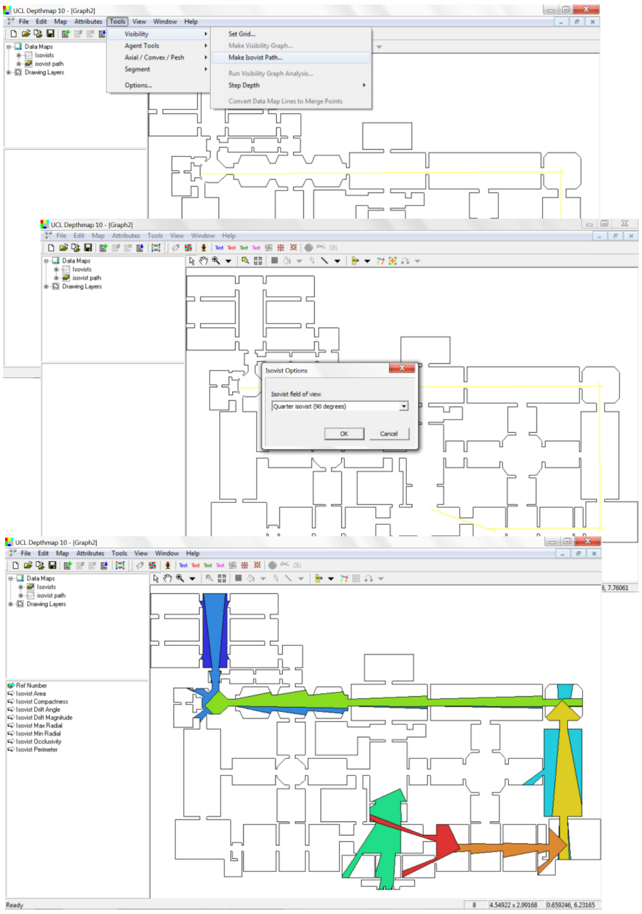
You will find that window again where you can choose one of the options for the isovist angle. If you choose quarter isovist (90°) you will see the red isovist in figure .



In addition to creating a point isovist, you can create an isovist path. To do that you have to create a new data layer in which you will have to draw some lines. You can spare this step if you have already drawn a path for your isovist in the CAD package you have and imported that into Depthmap as a drawing layer. Since you have not done that you have to resort to drawing your path manually in Depthmap. Create a new layer from MAP→ NEW. Choose the data map and name it isovist path.



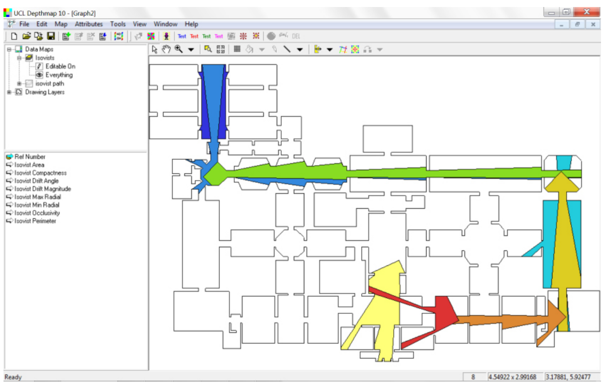
Using the line icon on your tool bar draw the lines that define the path on your layout. Make sure that you draw the lines following one direction and make sure that the lines intersect at their ends.



Make sure you select these lines and go to TOOLS→VISIBILITY→MAKE ISOVIST PATH.

A window will appear providing you with several options on how to define the isovist's field of view.

You can keep the default (quarter isovist) and the results appear.
They will be added to isovists you have created previously.

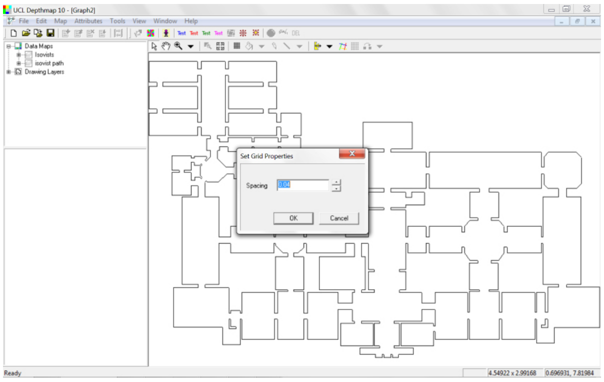


If you don't want to see other isovists you can try to delete them by turning editable on in the isovist layer and then selecting isovist one by one and deleting them. Make sure you save your file before that.

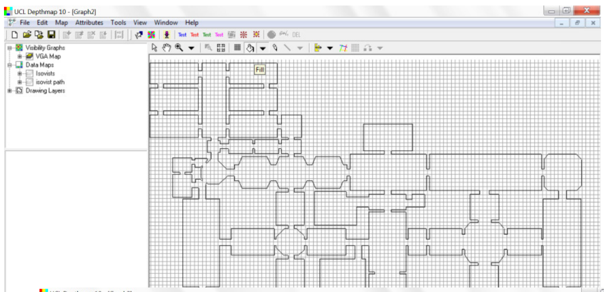
4. Prepare your graph for calculating visibility properties

Up to this stage you were dealing with the direct layout boundary to produce basic and localised visual properties of it. In order to analyse visibility relationships on a complex and global level you will have to use the visibility graph analysis model[10].

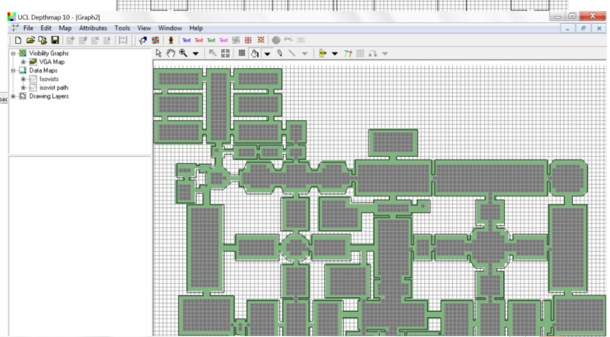
[10] The model has been developed by Alasdair Turner and implemented by him into UCL Depthmap. It aims to calculate visibility relationships that are similar to those of Space Syntax basing that on a finer level of representation; that is the scale of the human body represented by a grid unit. The connections are then made on the basis of inter-visibility between two units in the grid that fills an area within a predefined boundary.



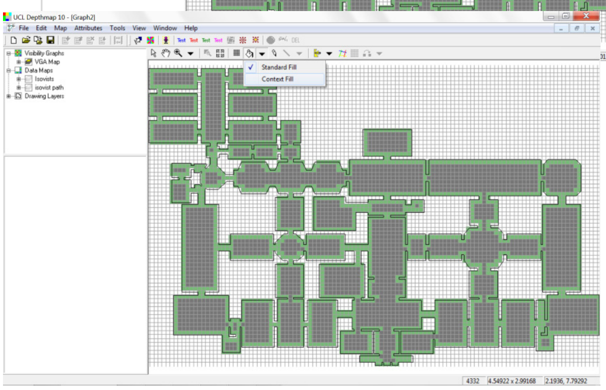
Create a grid by clicking the icon . Define the grid spacing in order to define the unit proportions. This will enable you to control the resolution of the analysis. Remember to choose a sensible grid spacing that matches the human scale (0,6 to 0.7m). I have chosen 0.5m.



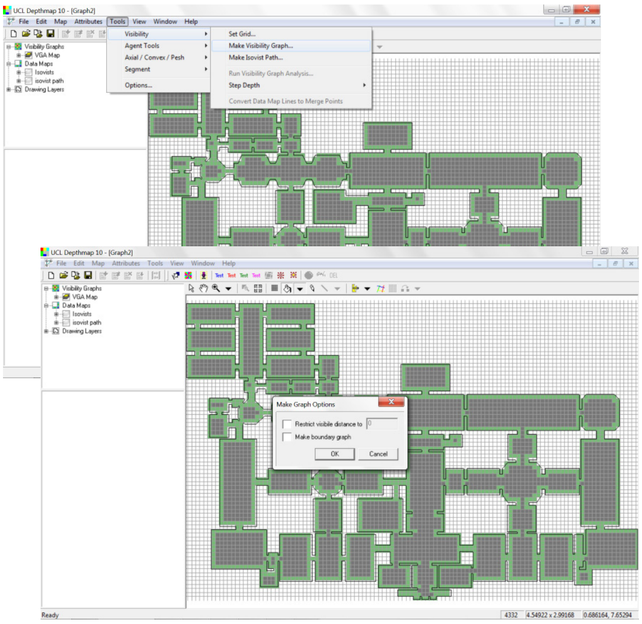
After you have defined the grid unit click OK. You will be able to see the grid overlaid above the layout and you will also find a new layer created on your left-hand side called VGA .



Click the fill icon on your toolbar to fill in the spaces you want to analyse within the layout. And click somewhere within the layout to fill in the area .

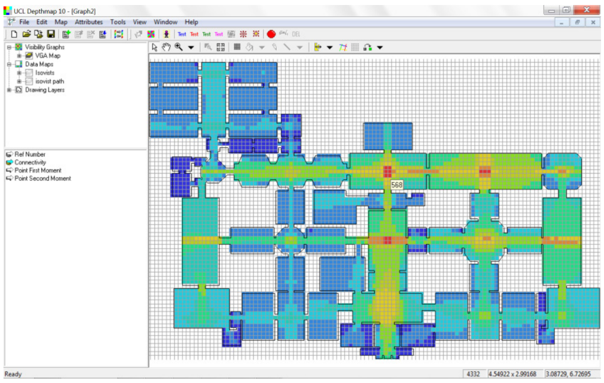


You can also try the context fill from the drop-down list next to the filling tool, although this tool is designed specifically for low resolution grid.
Also, you can fill in grid spaces in case you had a very precise pattern that you want to analyse. You can do that using the pencil tool in your toolbar . you can also block grid spaces by right clicking them.



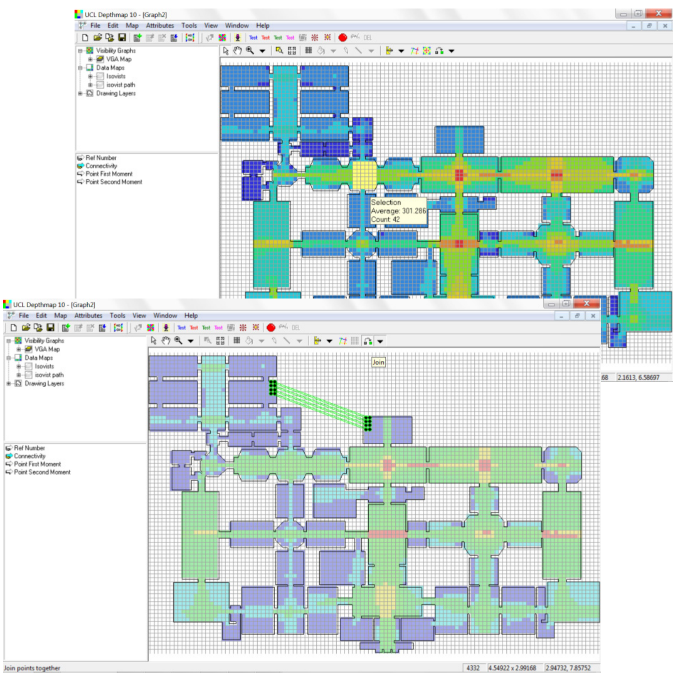
After you are done defining the spaces you want to analyse, go to TOOLS→ VISIBILITY→MAKE VISIBILITY GRAPH.

A window will appear giving you the option of restricting graph distances to be calculated within a certain metric radius. This is in case you had large areas to analyse and you did not find the standard graph analysis to be representative of the real situation.
Another option given by this window is to analyse the boundary of the graph rather than the spaces. This is in case you were interested in the boundary visual configurations of the occluding walls.
For the scope of standard analysis, you can ignore these two options and proceed by clicking OK.



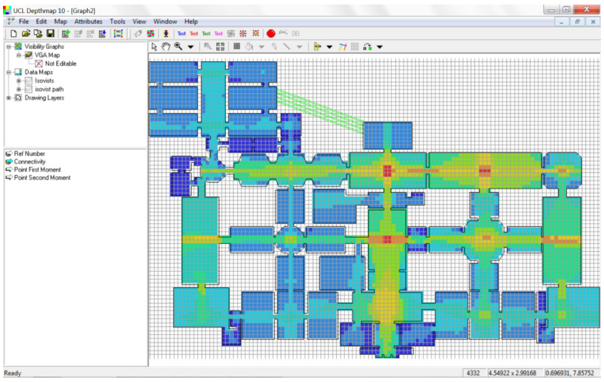
At this point a visibility graph has been made. You will be able to see some graph measures on the lower left hand corner. Simply, they include the reference number, the connectivity value and two other measures called point first moment[11] and point second moment.

[11] The first moment is a mathematical concept. For mathematicians: it is the first moment about the generating point for the isovist, not its centroid. Depthmap defines it as the sum of the distances from the generating point to every visible VGA grid point.



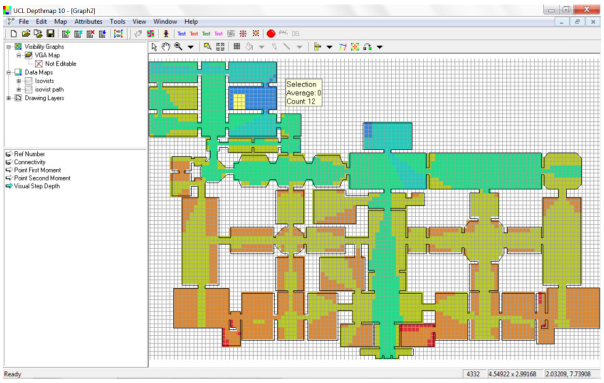
After you have arrived at a visibility graph you will see the joining tool enabled. You can now select grid points on one end and join them to the same number of points on the other end that look for the first instance as not directly visible. This is in case you had certain transparent material separating spaces, also in case you had some opening between two different levels. This also includes cases where you have staircases, although in this case the decision of joining is left to the convenience of inter-visibility between levels having them joined by stair cases. If you have done mistakes joining nodes in the visibility graph you can always unlink them using the unlink tool .

Once you are done joining your graph nodes,

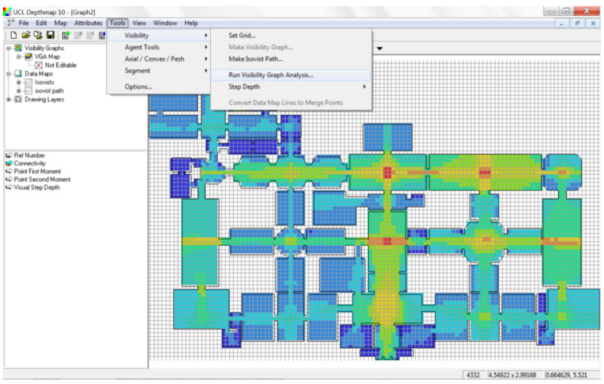


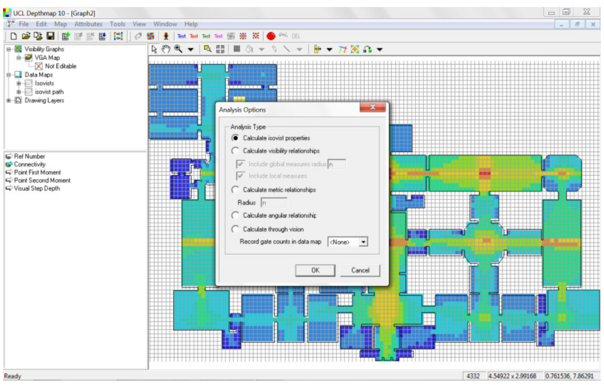
you will be ready to analyse visibility relationships in your graph. You can click the selection tool but you will still be able to see the green linking lines in the background of your visibility graph. If this lines disappear after a while don't worry you can always check them again when you switch to the joining mode.

5. Moving on to Visibility Graph Analysis

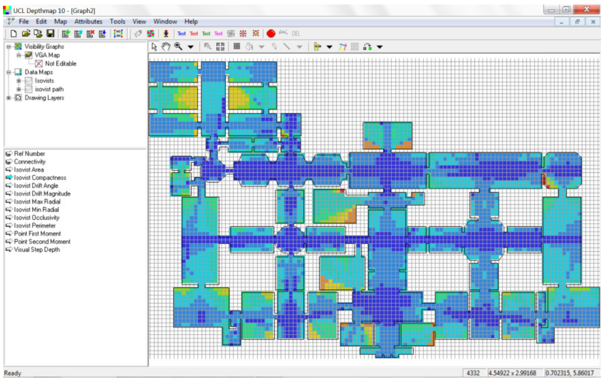


At the moment, the only measure you can calculate is visual step depth. In order to do so, you will have to select a node or more and calculate step depth by pressing on the icon . The red colour indicates deeper areas from the selected nodes. It means that you will have to go through several visual steps to be able to see these areas. You can still reverse the colours using to keep the conception of red as the most shallow/integrated locality in a spatial or visual setting.

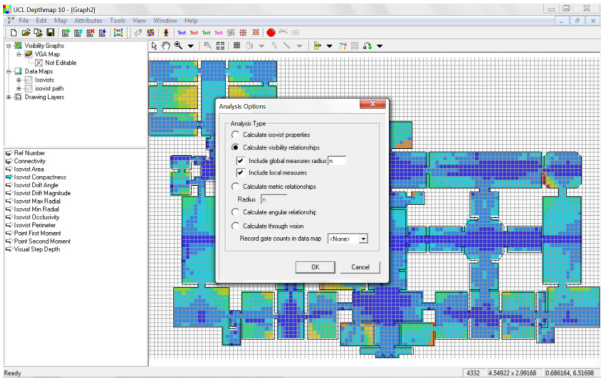




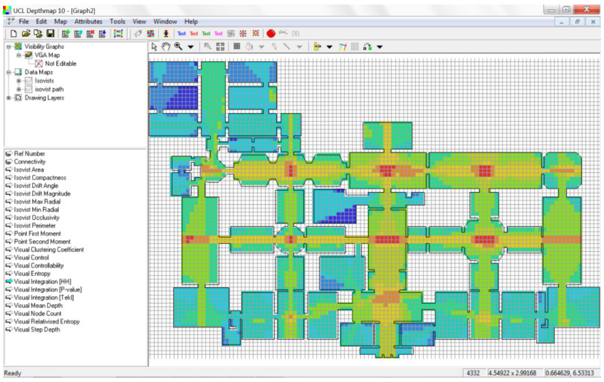
In order for you to go further with the visibility graph analysis go to TOOLS→ VISIBILITY→RUN VISIBILITY GRAPH ANALYSIS. A window will appear giving you several options.
One option is to calculate isovist properties; this would render the aggregate isovist properties for every single point in the grid as a generating point of an isovist.
Another option is to calculate visibility relationships. This is the standard option that you will use for calculating graph measures similar to those of convex and axial analysis. The node here stands for a node in a graph instead of an axial line or a convex space. The edges represent inter-visibility between two nodes rather than intersection between two axial lines or doorway between two convex spaces.
The rest of the measures are intended to mimic the effects and measure of axial and segment analysis.
Metric and angular analysis will calculate physical distance and angular turns between the nodes in the visibility graph; creating effect a model that is similar to segment maps.
Through vision will look for longer lines of vision and hence act as an axial map.



If you choose to analyse Isovist properties you will find that several isovists measures appear on the lower left hand side.
Some of these are physical properties that we have introduced previously. Other measures include; compactness, drift, radial and occlusivity. Explanation for these measures is in the previous section.



If you go back to visibility graph analysis window and you choose to calculate visibility relationships. Make sure you check the include local measures box, this is to include measures such as visual control, controllability, and clustering coefficient.

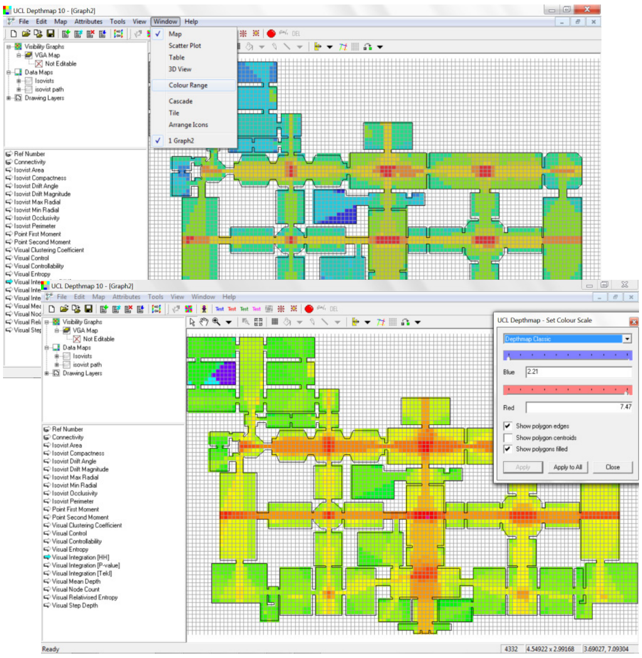


Once you click OK, you will be able to see all other measures listed in addition to the isovist measures you have analysed previously. You will see some measures that might sound interesting to you like entropy. However, the most profound measures are integration and visual clustering coefficient. Visual control and controllability might be of value to you depending on the scope of your research. Similar to integration in a convex map, visual Integration is representative of potentially core area in the layout where one can see much of the layout and can be easily seen. We can't really establish that people will want to be in such areas, may be if they want to see much of the layout and communicate with others. Visual clustering coefficient is indicative of both convex maps and axial maps if you put them together follow the representation of the visibility graphs. By default red areas are more convex like and might be potentially occupational spaces. Blue areas are more elongated and might prove the nature of these areas to afford high movement activity.

Save your file

6. Changing your colour range

In order to read differences more clearly between high low values of each measure you can change the colour range. This is just for the purpose of data visualisation and will have no effects on the values of elements themselves.



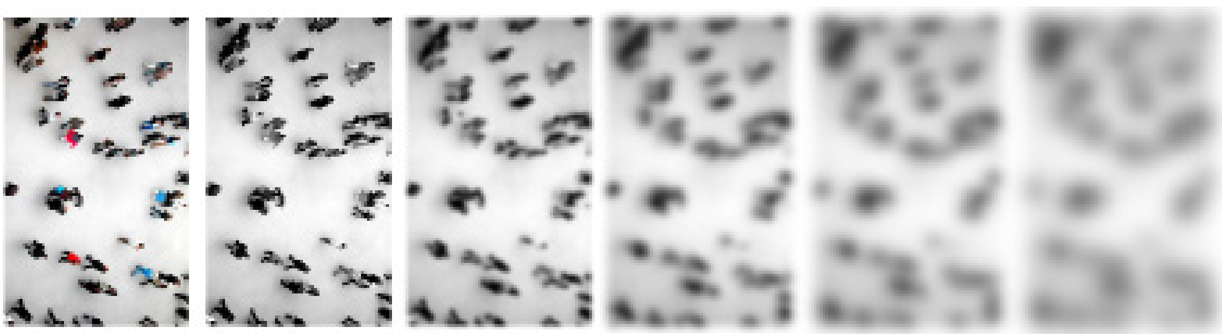
Go to WINDOW---COLOUR RANGE.

A window will appear. Use the browser to move to Depthmap classic as a banding range type. Adjust the sliders in such a way as to find a satisfactory representation of the data values in the visibility graph.

Please bear in mind that when comparing different systems you need to unify the ranges by setting the same min and max limits.

Save your file if you intend to keep the amendments you have made on the colour range.

OBSERVATION TECHNIQUES



INTRODUCTION TO OBSERVATION TECHNIQUES[12]

[12] This section on observations is adapted from a manual written for the Space Syntax Laboratory by Tad Grajewski in 1992 and rewritten by Laura Vaughan in 2001.

Introduction

This chapter addresses the description of field observations on pedestrian flow and static activities in the urban environment. Before designing and conducting observations, field visits are normally organised to build a preliminary understanding of the site conditions and settings, marking key functionalities or land uses in the layout and making initial decisions on where to allocate observation areas. For the purpose of constructing a quantitative description of the movement behaviour in the public realm, consistent and well-structured observations on site are usually designed to measure real movement and occupational behaviour and test spatial predictions. In the sections that follow, we will explain the observation methods and how these observations are conducted on site. The observations are normally allocated in certain locations to ensure a comprehensive coverage of the movement and occupation activities within target areas. The methodologies explain can only act as guidance tips, special considerations can be made to the particularities of each research or design project.

Why do we observe?

We observe in order to see how much we can learn about the environment without taking account of people's intentions. People normally say why they are going somewhere if asked, not how they plan to get there, or what they are going to do on their way. The collective activity within buildings or urban contexts gives rise to a pattern of use and movement that is independent of the intentions of individuals. Observations allow you to retrieve something that might be considered as an objective view of human behaviour in the built environment. However, in doing observations, some precautious measures should be taken especially when an observer is regarded as a participant in the social sphere that occupies the spatial scene.

Observation methods overview

Space Syntax Observations are a set of techniques to observe movement flows and patterns of space usage in complex buildings or urban contexts. These techniques are developed specifically for Space Syntax Research, yet they do resemble methods used in other disciplines and fields.

To design our research we use a combination of methods (e.g. surveys and landuse maps, time-lapse photography, questionnaires, interviews etc.) that are most suitable to our research question. There are different methods to perform an investigation into social behaviour. We will discuss some of them in the following sections.

1. Gate counts

Gate counts are usually directed to observe the density of pedestrian or vehicular movement flows in a building or an urban layout. Gate counts allow researchers to collect a great deal of data which can be represented graphically and statistically.

The method must be applied with rigour and consistency at many locations.

To conduct observations, we usually choose a number of locations that cover an area under study. We cover a range of well-used, moderately-used and poorly-used spaces in and around the boundaries of the target area. We then choose a reasonable number of 'gate' positions, around 25 gates or more. Each gate can be observed for 5 or 2.5 minutes –depending on how quite a gate is- over regular intervals (i. e. four or five times) during working days and weekends. Observers are to stand at the edge of each gate to maximize their visual field and count people crossing an imaginary line that ideally connects two parts of the built environment e.g. columns, walls (figure 6.1). They may use stopwatch to perform the counting precisely. Some gates can be divided into two or more when there are dense movement flows that affect the feasibility of counting. Information can be recorded on special tables, where numbers of pedestrians passing by might be logged in addition to special notes on the time, date, weather conditions and other special factors that might affect the course of observations (figure 6.2). On the gate count tables, it helps to note categories as accurately as possible, although erroneous assignment of categories is inevitable where there some ambiguities in the characterization of a certain type of pedestrians. Categories can be delimited by age, profession, status such as students, visitors, tourists, locals, …etc. It is always a good practice to do as many categories as possible. This helps formulating the research question in some cases. It also helps understanding the problem conditions of the site under study. Researchers may aggregate the categories later to inform their own investigation (figure 6.3). The counts of movement are usually helpful in understanding the relationship between spatial structure and human behaviour (see figure 6.4).

In designing the research, observers should account for what is relevant in relation to their research question, how the site is used. They should also note that in the UK, Fridays, Saturdays and Sundays tend to be different. So before starting their research they should think about how often and when they should conduct observations, and whether weekends are relevant at all.

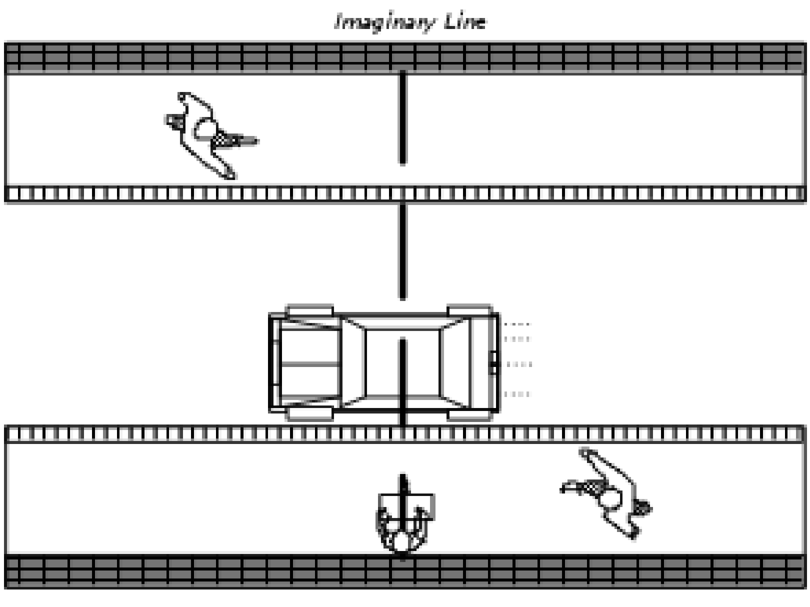
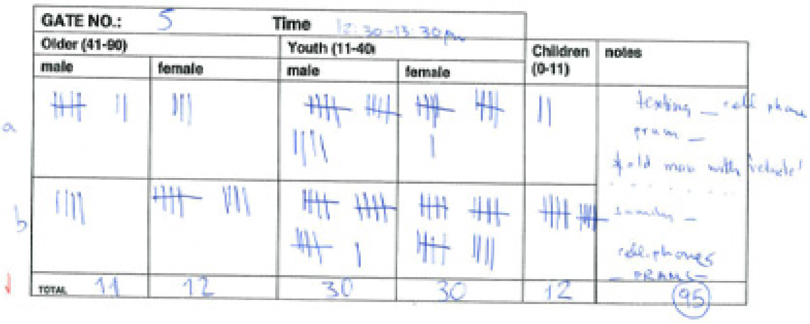


Figure 6.1. Position of observer in relation to the observed gate. The observer was to count pedestrian movement that crosses an imaginary line (adapted from Laura Vaughan).



GATE NO.: 5		Time 12:30-13:30pm			
Older (41-90)		Youth (11-40)		Children (0-11)	notes
male	female	male	female		
a					texting — cell phone pram — fold man with bicycle!
b					smoking — cell phones — PRAMS
TOTAL 11	12	30	30	12	95

Figure 6.2. A sample of the gate counts table marking gate number, time of observation task, age category, and a tally count of the number of people passing by the gate. Special notes were also recorded in relation to weather, use of IT equipment, and special site-related conditions such as closure of underground station…etc. Source: Screens in the Wild @UCL.

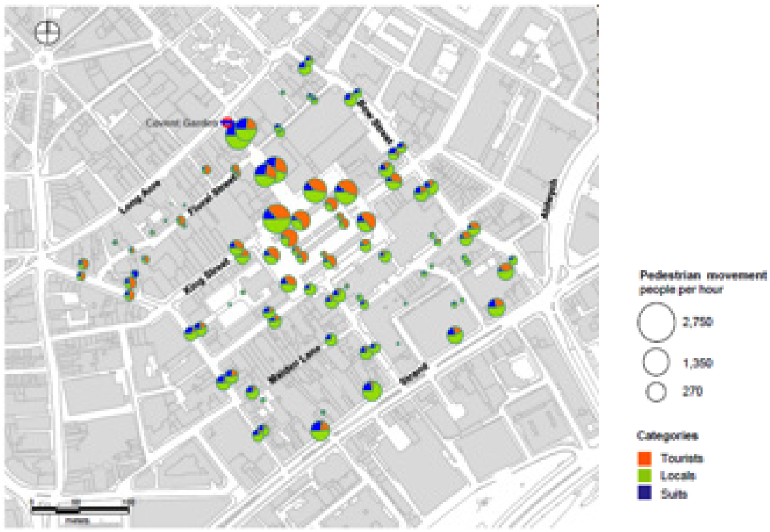


Figure 6.3. A map showing the average number of pedestrians per hour observed at the weekday crossing specific cordon lines in Covent Garden, London. Pedestrian flows are categorise to recognise tourists, locals and workers dressed in suits. Source: Space Syntax Ltd. 2007.

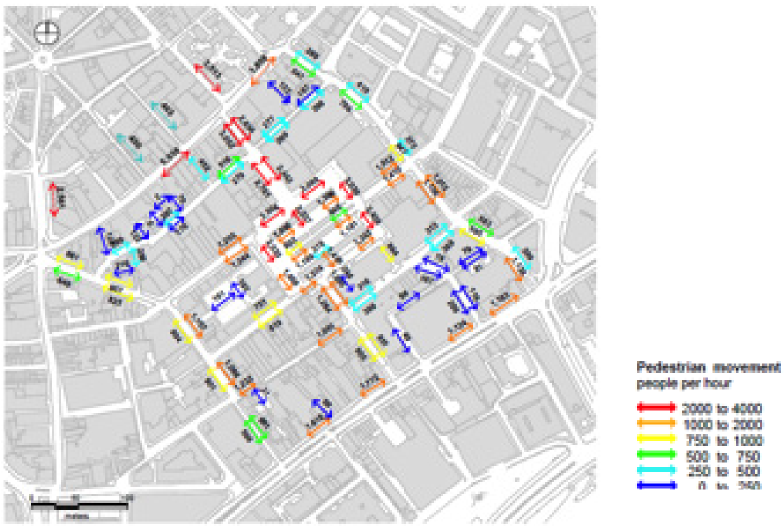


Figure 6.4. A map showing the average number of pedestrians per hour observed at the weekend crossing specific cordon lines in Covent Garden, London. Source: Space Syntax Ltd. 2007.

2. Static snapshots

Normally, static snapshots are conducted to record the use pattern of spaces within buildings or public spaces in an urban context. The method is useful for comparing static activities (standing, sitting) and movement. By tracking and mapping these activities in time we may outline the patterns of space use in an area and spot the locations where more potential interaction takes place naturally. In general, snapshots might be comparable to a photograph taken from above showing one moment of activities mapped onto the floor plan. They are usually taken at consistent intervals during the day, to provide an objective view of the invariant patterns of activity as well as different and peculiar behaviour throughout the day.

To conduct snapshots, we predefine areas that can be easily observed and positions at which an observer could maximise visual exposure to the observed field of study and at the same time minimise his/her own visibility to the users. We use a large-scale (1:50 minimum) floor plan to note categories and activities (sitting, standing, moving, interacting) for a period of five minutes over regular intervals during the day (see figure 6.5 for an example on snapshots). Other particularities that relate to weather conditions, peculiar behavioural patterns, IT use, or site settings can be marked in written text on observation sheets.

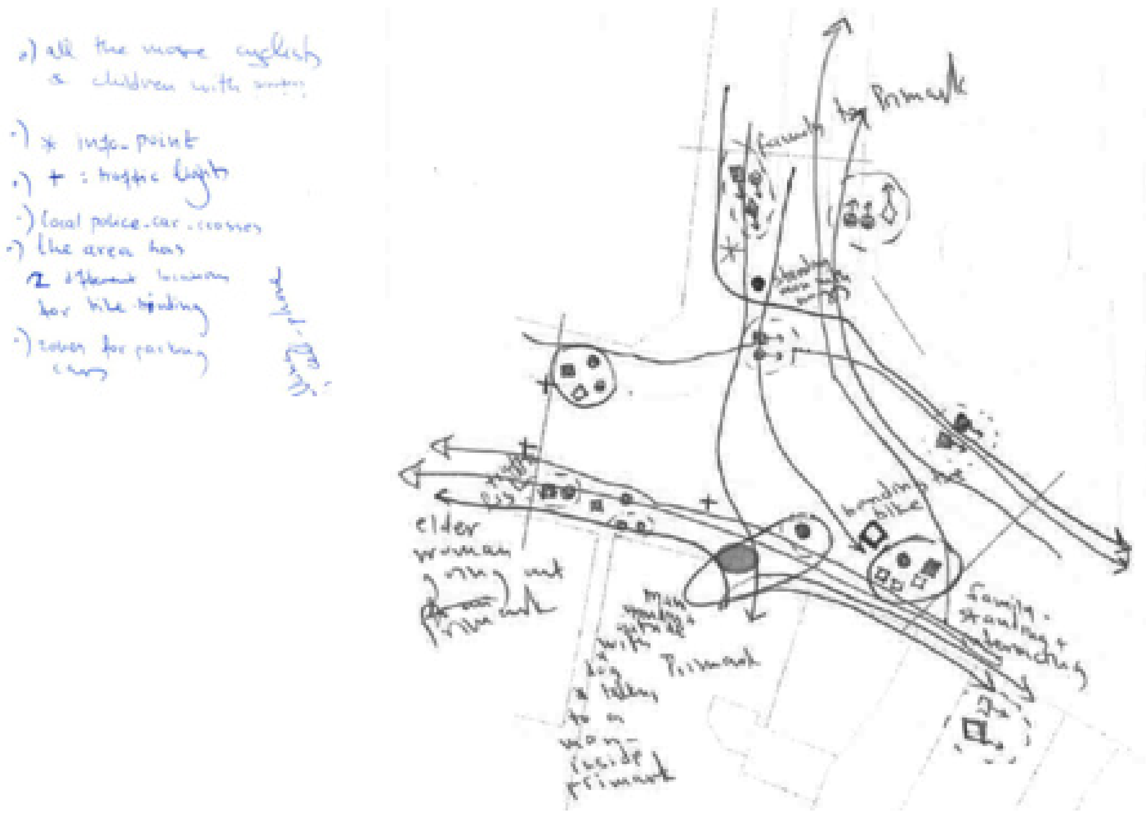


Figure 6.5. Movement traces and static activities are drawn on a 1:50 plan of the target area.
Notes on behavioural patterns and special features and conditions are recorded. Source: Screens in the Wild @UCL.

3. Movement traces

Movement traces enables tracking and mapping the collective flow dynamics through a predefined area. It helps understanding movement patterns and where people are likely to enter/exit the area from (see figure 6.6). Observers might also be able to outline islands where no movement traffic is recorded. Similar to snapshots, target areas are normally chosen to have a convex layout that is easy to observe. The observers position themselves in locations that maximize their vision of the layout and record movement for 5 minutes at several time intervals throughout the day. They are encouraged to use coloured pens to mark different categories on the layout.

Observations are usually conducted on site to empirically track and map human behaviour. They are mainly directed to test the spatial models we have derived earlier from the visual configurations of the urban layouts.
Where a correspondence between both observation and space exists, it comes as to validate and support our assumptions on the role of spatial visibility and access in promoting certain spaces to be more hostile for human encounter and interaction. Where there is less correspondence, further investigation is needed to define any external attractors or outliers in the environment.

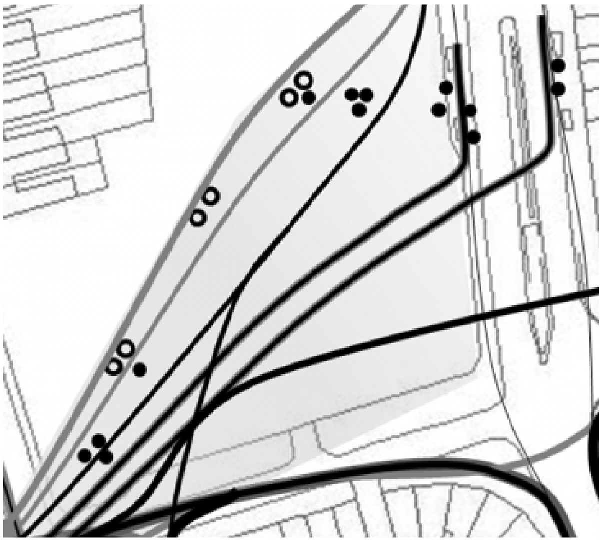


Figure 6.6. Movement traces and some static patterns are drawn on a 1:50 plan of an urban area. Source: Screens in the Wild @UCL.

4. Traces (People-Following)

Tracing people is an important technique to observe movement flows that are 'dispersed' from a specific movement distributor, e.g. a train station, a shopping mall, entrances to buildings. It can be used in urban contexts as well as in buildings. There are three distinct issues that can be investigated through the use of this technique: 1) patterns of movement from a specific location; 2) relationship of one route to other routes; 3) average distance people walk from one location (e.g. to study the catchment area).

For the purpose of tracing, we first use plan of the whole area of interest. In urban contexts it will be useful to arrange the plan so that the pick-up point is at the centre of the plan.

To rule out bias in the reading of movement behaviour, observers should pick up people randomly as they start a journey from a predefined point of origin and follow them tracing their route. The tracing might be stopped either when people leave the area of interest, reach a pre-defined destination, or after a fixed period of time (e.g. ten minutes). It is important to be discreet in this process – people should not become aware that someone is following them. It is always good to account for a mix of people (age, gender, other categories of interest) and note details for each trace. Tracing is a very useful technique when comparing movement behaviour from a particular point of origin in a layout (an entrance). It is usually used to display visual comparisons between spatial analysis (VGA) and movement traces (see figure 6.7).

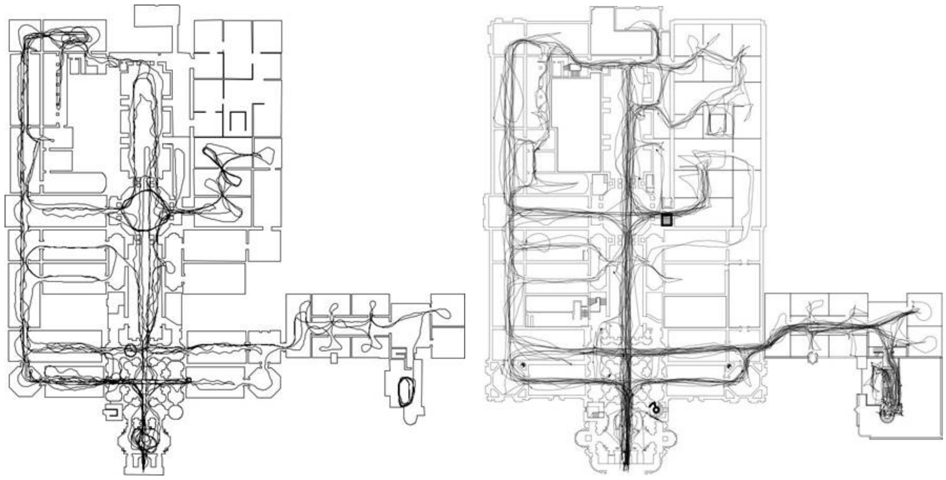


Figure 6.7. A comparison between agent traces (left) and observed movement traces (right), drawn on the Tate Modern layout space. Source: Alasdair Turner@UCL.

5. Ethnographic Observations

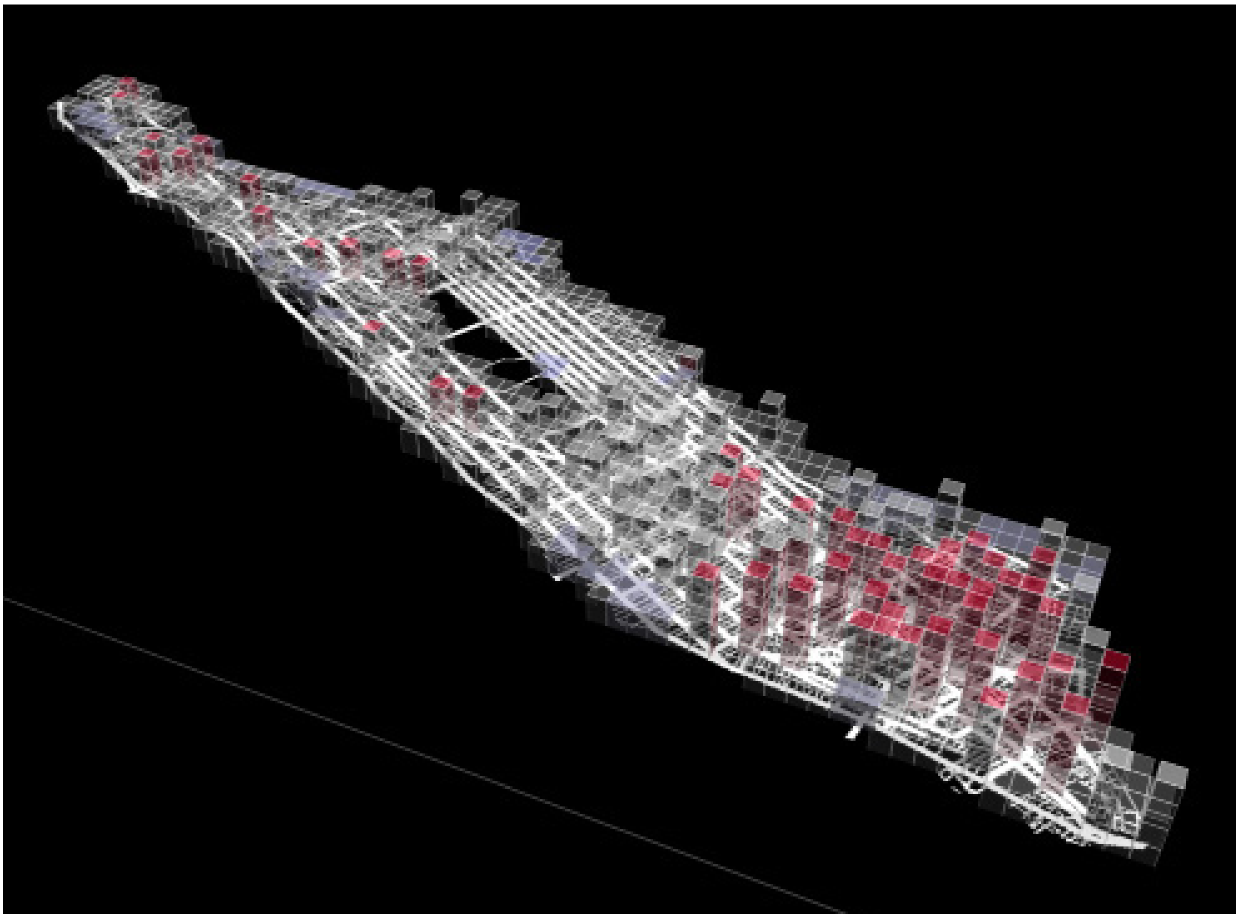
Ethnographic observations are especially relevant to understanding qualitative issues of space usage within buildings, but are also applicable to the observation of the public realm. They are useful for understanding and unpacking social phenomena and complex relationships of cause and rationales. Further to the patterns revealed by previous methodologies, ethnographic observations add depth and richness to a research narrative.

To conduct ethnographic observations, an observer needs to take part in the life of the observation field as discreetly and unobtrusively as possible – behave like one of the observed subjects (role as "participant observer"). The observer should seek as much detail as possible in the description of events and occurrences taking place in the observed environment. This will add to the richness and precision of the observations. The observers are encouraged to take notes / pictures, make sketches of what they see, hear, smell or feel. The observers are also encouraged to let their observations guide them from a more open-ended observation to a more structured observation of certain phenomena. In representing data, observers are required to be careful about how they interpret what they see and how they make sense of their notes. When possible, observers can combine the information they acquire from the environment with other relevant data and information.

Observation tools

Alongside manual counting of movement, different technologies were used (i. e. Bluetooth devices were used by Ava Fatah Gen Schieck in her research on digital identity and performative interactions). Recently, there were developments on pedestrian movement count tools that led to the introduction of new software tools such as PedCount and People Watcher. PedCount is software-as-a-service by Strategic Spatial Solutions, Inc. The software is available at https://github.com/s3sol and is free for academic use. People Watcher is a data collection tool written by Sheep Dalton and available as a free application on iPad at https://itunes.apple.com/gb/app/people-watcher/id523155791?mt=8

DATA
ANALYSIS



INTRODUCTION ON DATA AND STATISTICS[13]

[13]This section was originally prepared by Alan Penn. Parts of this section are adapted from a paper produced by the Cathie Marsh Centre for Census and Survey Research at the University of Manchester. Other material is adapted from JMP and the Statview manual 'Using Statview', Abacus Concepts Inc, Berkeley, California.

Introduction

Data are collections of information. Traditionally in Space Syntax data are used to understand and test the relationship between space and society. Data can take any form, for example interview transcripts and field notes. The type of data collected will influence the sort of analysis that can be used to interpret them, and academic disciplines develop research methods to reflect this.

Aspects of data

A key distinction made in social research is that between quantitative and qualitative methods. Although these methods have much in common, they differ in the sorts of data that are collected and the techniques applied to understand them.

Qualitative data is descriptive data, which can be collected by means of in-depth interview, field observations or from other sources such as newspapers. The data is generally quite detailed and is aimed to understand motives, understandings, feelings and social processes, particularly at the small scale. Researchers using this sort of data usually are attempting to explain social behaviour within a set context, and rarely attempt to make claims about behaviour outside of this context.

By contrast, quantitative data is data that is being used to understand questions like:

- How many children under the age of 11 truant from school?

- In general, do people living in inner cities prefer to drive or to use other forms of transport?

- Data used for this sort of research question has to contain either information that is measured, or data that is suitable for being counted.

One very important type of quantitative data is that which contains a standard amount of information about a number of different things or people. This is the sort of information that is gathered by a survey; interviewers ask the same questions of a large number of people so that they can investigate the extent to which individuals' responses differ, and whether there are discernible patterns. This sort of data is generally (although not necessarily) collected from a representative sample of individuals so that conclusions can be applied to a wider population; a common way to choose individuals who are representative is to take a random sample. When data is produced in this way it is appropriate to use statistical methods and conclusions subsequently drawn are said to be 'generalisable' to a specified population.

Quantitative data comes in different varieties. The extent to which each is used and the way in which they are classified varies from discipline to discipline. Some key distinctions are as follows:

Primary vs. Secondary Data

Primary data are data that have been specifically collected for a particular study, either via a survey or other means (including interviews and observation). Secondary data are those which have been collected by some other person or organisation, but which can be re-analysed for other purposes.
There are advantages and disadvantages to each approach; primary analysis allows researchers an in-depth understanding of how the data were collected, but is expensive and time consuming.
Secondary data are generally cheaper to use and permit researchers to explore very large datasets. However, the usefulness of the secondary data is limited by the secondary analyst's ability to identify a dataset that is fit for purpose and to understand how the data was collected and what the values mean. Key sources of secondary data include the large government datasets (e.g. the General Household Survey, Farm Business Survey, British Household Panel Study and Labour Force Survey) and the Census.

Population Data and Sample Data

If one is interested in studying all the people living in the U.K it is very easy to define what the population is – it is simply the population of the UK!
When researchers design a research project they decide which set of people they are interested in, so for example, a researcher interested in patterns of travel to work may be interested in every individual aged over 18, or every individual between 18 and retirement age.
Every single individual in that set of people (or households or businesses... etc.) collectively constitute the population of interest. So if, for example, we were interested in studying patterns of travel to work within central London, our population would be everyone currently working in Central London. If we were a governmental institute interested in discovering transportation needs for London's commuters, we would want to ask this population a set of question about their travel patterns and anticipated needs.

However, when we are collecting data we only very rarely try to collect information from everyone in the population, it is usually too costly and too difficult. We know that if we take a representative sample of the population we can cut our costs, but obtain reliable estimates of the true characteristics of the population as a whole.
Surveys obtain data for only a sample of the population. The extent to which the sample is representative will depend on the sampling method chosen. There are standard tables for determining a statistically significant sample. See appendix to this section.

Thinking about where the data came from

Unless you collected your data yourself it is quite possible to be mistaken about its nature unless you do some research to find out where the data came from, how it was collected, what it was collected for and how the data was coded.
The answers to these questions will be helpful in determining how useful the dataset is likely to be for your own research.

Statistical Methods

Many statistical techniques are designed for analysing a representative sample of micro-data from a population. Statistical methods are a 'toolbox' of formal techniques for analysing quantitative data; that is, data that can be expressed numerically. Statistical techniques can be used to undertake a wide range of tasks including:

- summarising characteristics of a sample,
- producing estimates of population characteristics,
- quantifying the accuracy of these estimates and,
- testing hypotheses.

Some techniques, especially the first two listed above, are designed for exploring and describing data, and characteristics of the individuals from whom data was collected. This is understandably known as 'exploratory data analysis). Others, particularly the second pair in the list, are designed to confirm conclusions drawn using exploratory analysis or test theories.

An understanding of the research question is as important to doing good research as an understanding of the concepts behind the methods. It is important to understand the nature of the statistical method and, importantly, its limitations, but most real world statisticians undertake their analysis using computer applications like Excel (which is not primarily for statistical analysis) or dedicated statistical analysis packages like SPSS, STATA, SAS, JMP, STATVIEW or MINITAB.

Variables

A variable is simply something that can vary, it is a variable characteristic of some sort (e.g. gender). In undertaking a statistical analysis we are often interested in finding out how things vary and whether these variations can be accounted for.

Variables may be categorical or continuous (the former being the more common in social survey or census data).

Categorical Variables (also known as discrete or qualitative variables)

Variables in which the values can be understood as categories are called categorical variables. All the values of the variable are defined and given a value label to indicate the meaning of the value.

An example of a variable of this type might be categorising streets in an urban study according to their principal land-use. You might categorise residential as (1) and shopping as (2) and office as (3). You can normally set up your statistics software to translate numerical categories into meaningful labels ('residential') and ('shopping') and ('office').

Categorical values have particular qualities. Most importantly, the numerical values in the data, because they represent categories, have no significance. It would be total nonsense to claim that, for example;
1 shopping street + 2 residential streets = 1 office

Categorical values can have a natural order. For example, the class classifications given by Booth, which amount to 7 categories, from '1-vicious lower class' to '7-upper class', have a natural order from lowest to highest class.
If you were categorising streets according to these values, you would normally have the lowest number for the lowest class, but this does not imply that the difference between being a member of the lowest class and of the second lowest class is the same as the difference between the two top classes.

- A categorical variable that has a natural order is called ordinal variable.

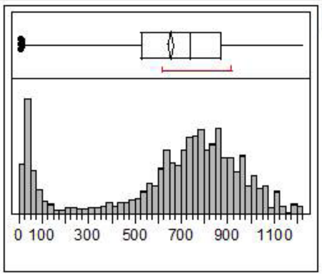
- A categorical variable that does not have any natural order is called a nominal value.

- A categorical variable that only takes two possible values is called a binary variable.

The easiest way to summarise the values for a categorical variable is to look at the frequencies.
A statistical package will produce a table of all valid values with a tabulation of the number of times the value occurs in the data (see table 7.1).
In JMP you need to select distribution, in the new window you will need to select the column for which you want to display the frequency of data - here the number of elements that have segment integration values falling within certain bands.

Distributions

intR2000 10



Quantiles

100.0%	maximum	1220.7
99.5%		1208.0
97.5%		1118.8
90.0%		994.7
75.0%	quartile	873.6
50.0%	median	742.1
25.0%	quartile	534.6
10.0%		48.4
2.5%		22.5
0.5%		13.3
0.0%	minimum	7.0

Moments

Mean	654.64432
Std Dev	321.08672
Std Err Mean	5.59534
upper 95% Mean	665.61501
lower 95% Mean	643.67362
N	3293

Table 7.1 This histogram shows the statistical distribution of segment integration values (R 2000metric) for Barcelona 1714. Source: Kinda Al Sayed@UCL.

Continuous variables (also known as metrical or quantitative variables)

In contrast, continuous variables have valid values that fall between a minimum and maximum and any value between the two is possible. The minimum and maximum do not have to be defined.

Age is generally measured as a continuous variable. The youngest age possible is zero years, the oldest ever person at the time of writing was 122. It is possible for a persons age to fall anywhere between these extremes. Where, as in age, a continuous variable has a meaningful zero point the variable is said to be a 'scalar' or 'ratio' variable. You can do multiplication and division sums with these variables as well as addition and subtraction. Being 0 years means that you've only just arrived on the planet; being 4 years old means that you're twice as old as a 2-year-old.

If the exact date of birth had been recorded then age could be defined in exact days of months. But if we look at year of birth instead of age in years the variable would have different characteristics. The 2-year-old and 4-year-olds given in the example above could have been born in 1989 and 1987 respectively. The difference between 1989 and 1987 is still 2, addition and subtraction can still be done, but multiplication and division cannot. The zero of year relates to a date in the Christian calendar 1987 rather there being a total absence of time, or age, before 0AD, so we say that the zero is arbitrary. Only when there is a real and meaningful zero point is it possible to do multiplication and division calculations with the values.

If we were simply to produce a table (table 7.2), with density as a continuous variable we would find that the output would be unwieldy, unless we defined other bands (such as 0≤10%, 10%≤20%, etc.).

Variable Types		
Variable	Values	Type
Street with Immigrant Settlement?	1=yes 2=no	Binary Have only 2 possible values e.g. yes/no (or male/female)
Marital status	1=single 2=married 3=divorced	Nominal (most limited data type) Categories but there is no natural order.
Social class	1=Upper 2=Intermediate 3=Middle 4=Partly skilled 5=Unskilled	Ordinal Categories which have a natural order, but it does not make sense to do algebra with the values.
Age	0-120	Continuous (most flexible data type) The number is meaningful and can be used for calculations.

Table 7.2.

Looking at variables

An obvious occasion on which the differences between categorical and continuous variables are apparent occurs when one wants simply to look at a summary of the values for a variable.

Why use graphics?

A single image can convey some very complex observations about the characteristics of a dataset. While you will normally be expected to produce commentary and analysis as well as data summaries, a well thought out and well-presented graphic can be more quickly assimilated than a complex table or commentary. Graphics are also a very helpful means of understanding the structure of a dataset and therefore form an important part of exploratory data analysis.

Computer packages often require only a few clicks to produce graphics that are pleasing to the eye and professional looking. But perhaps the most important stage in producing any graphic or other statistical output is deciding which technique to use and why. The decision that you make will depend on your research question.

DATA ANALYSIS

You are likely to have a variety of types of questions about your data:

What?

Data resulting from a spatial and observation analysis of an area of London would produce results on line length, radius n integration and number of men, women, children per street (perhaps categorised by age groups), male/female etc., all of which might be addressed graphically:

1. What is the average (mean) control value for the map?

2. What proportion of streets on the map have movement rates above average?

3. What is the frequency of each person type? In other words, how is user category distributed?

4. How do the ages of person types vary? I.e. are men's and women's age distributions different?

5. What proportion of streets are shopping streets?

Why?

Some of these questions require further clarification. A seemingly simple question like Q3. might lead us to ask whether we are more interested in the distribution of age groups or of the type of person using the streets. Sometimes grouping categories allows us to see more easily what we are interested in, and sometimes we are only interested in certain age ranges. Decisions of this type can only be made if we ask why we are interested in a particular question.

1. Data types and analytical results (graphics)

Research questions may need different numbers of variables or different types of variables to answer them. Those using a single variable are univariate; those using two variables are called bivariate and those using more are called multi-variate. You need to select the analysis which best suits the research question and which is most appropriate to the type of data collected (sometimes you can transform data to a different form to allow them to be analysed).

2. Univariate Techniques for Categorical Data

Univariate techniques show the frequencies with which each category of a variable is observed in the data – the spread of observed values across possible values for a variable is called a distribution. Looking at a distribution is an important starting point in getting to grips with any dataset.

Univariate techniques are excellent at showing how variables are distributed. Remember that when dealing with categorical data the values that are recorded are given labels and, if nominal, will not have a natural order.

- Pie Charts

Pie charts are all about shares, proportions and percentages. The pie chart is drawn as a circle (the supposed pie) which represents 100% of all cases and 360°. Slices represent the share of the cases with which fall into each category of the variable in question. The slices are sized so that 1% of cases are represented by a 3.6° sector of the pie. Pie charts are useful when you are considering a whole population as they show all cases.

- Bar charts

Like pie charts, bar charts can easily be produced for small datasets, or from a frequency table. As with pie charts the size of the bar is representative of either the number or percentage of the cases falling into the category in question. The categories do not have to have a natural order, although where the variable is ordinal the order will be given in the chart.

Most packages allow you to define the scale (on the y-axis) against which the bars are measured – and the wrong choice of scale could be misleading. Whether you choose to represent the data with raw figures or percentages will depend on the size of your sample and whether there is a logic to making the sub-groupings.

In general: you might want to lock the scale to compare different samples for which the same measure has been taken (e.g. control for a whole map and a sub area of the map).

3. Univariate techniques for continuous data

The techniques described above are those suited to variables with a small number of discrete values. If continuous data were used in either a bar chart or pie chart you would obtain a bar or slice for each value and the important characteristics of the data would get lost in the (cramped) detail. To get around this problem, there are other techniques which either group the values or which summarise the characteristics of the variable, rather than simply counting the frequencies for each value. These include histograms and box plots. We will only describe Histograms here.

- Histograms

The simplest approach to graphically representing a continuous variable is a histogram. This technique is very similar to that of a bar chart, however, while a bar chart represents each discrete value with a bar, a histogram groups together adjoining values. Because a bar chart deals with discrete data, good statistical packages will usually place a gap between neighbouring bars. In contrast the bars in a histogram touch, indicating that the data is continuous. Histograms have the same issues of presentation as bar charts, but, in addition, one has to consider how to group values. Statistical packages will group values naturally by some default rule, but most will allow you to change the way in which values are grouped using an option or subcommand.

4. Bivariate or Multivariate analysis: Scattergrams

Sometimes a research question requires you to look at more than one variable, often to see if there is a relationship between the two. Your questions might include: Is there a relationship between radius n and radius 3 integration?

Scattergrams are primarily used to explore relationships between 2 continuous variables. Simple scattergrams are composed of a multitude of points marked on a graph with two axes, one axis for each variable. Each point represents a single case. For illustration we can plot segment integration (see chapter on segment analysis) radius n against radius 2000metric for the map of Barcelona, 1714. In JMP this is known as Bivariate Fit. The scattergram in Depthmap is probably equivalent to that. It is useful to find how recognized clusters might have certain spatial distribution. In our case we see elements that represent high correspondence between the local and global segment integration are more representative of compact urbanized areas. An example for that is in figures 7.1 and 7.2.

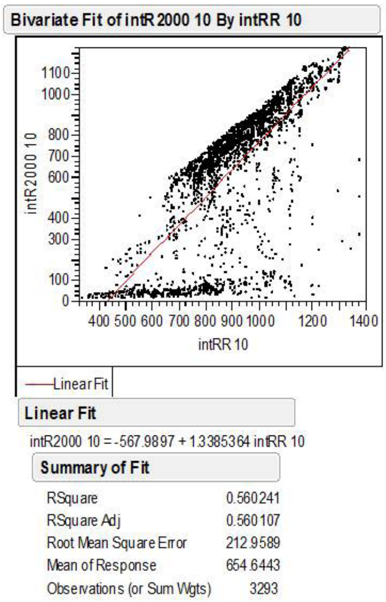


Figure 7.1. This scattergram shows us an R-squared value of 0.56 between segment integration radius 2000 metric and segment integration radius n for Barcelona 1714. The Bivariate Fit is produced using JMP software.

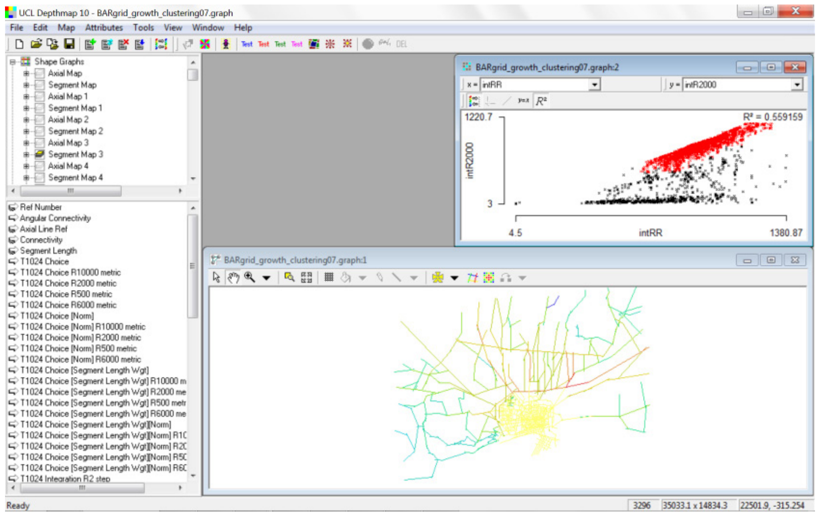


Figure 7.2. The Regression here is similar to figure 7.2. UCL Depthmap is used to produce the correlation scattergram. By selecting the group of elements that have the highest correspondence (closer to regression line) you could see where they are placed on the map. Source: Kinda Al Sayed@UCL.

There are many other ways of 'interrogating' scattergrams. First, you should always check the p-value, to see the probability that a result occurred by chance. Second, look at outliers: which values are under-performing or over-performing (are not following the regression line). Does their exclusion create a better correspondence (only exclude if there is a logic, such as excluding one-connected streets and always mention you have done this in the text).

Why do you think these values are not performing like the others – is your data accurate? Is there an anomaly in the results – you may discover new things about your data through this process.

5. T-Tests

A t-test works by comparing the average value of a group or sample with the average value of the population as a whole, and asking how likely it is that the average of the smaller sample would have been arrived at by chance. The degree to which the two averages differ is indicated by a t-value where a high number (positive or negative) indicates greater difference – this expresses the difference between the mean and the hypothesized value in terms of the standard error. The probability that this could have happened by chance is indicated by the p-value, where the smaller the number, the less likely to have occurred by chance and the greater the significance of the result. Probabilities of less than .05 are generally considered to be statistically significant; p-values of close to 1 mean that it is very likely that the hypothesized and sample means are the same.

APPENDIX: GUIDE TO DETERMINING QUESTIONNAIRE SAMPLE SIZES

Table of sample sizes for different sizes of population at a 95% level of certainty (assuming data are collected from all cases in the sample[14]

	MARGIN OF ERROR			
Population	5%	3%	2%	1%
50	44	48	49	50
100	79	91	96	99
150	108	132	141	148
200	132	168	185	196
250	151	203	226	244
300	168	234	267	291
400	196	291	434	384
500	217	340	414	475
750	254	440	571	696
1000	278	516	706	906
2000	322	696	1091	1655
5000	357	879	1622	3288
10000	370	964	1936	4899
100000	383	1056	2345	8762
1000000	384	1066	2395	9513
10000000	384	1067	2400	9595

[14] This table is based on a document provided to Laura Vaughan by RM Consult-

What is a "margin of error"? If you remember that a sample of a population is meant to reflect the characteristics of the population as a whole, the margin reflects the percentage by which the results are likely to deviate (plus/minus) from those characteristics. Thus, if your survey shows that 14% of visitors to Camden Market who responded to the survey are from abroad, you would expect that 14% of the entire population would also be visitors from abroad. If your sample was within the 2% margin, you would know that the percentage of visitors would range, at the most, between 12-16%.
The higher the margin, the more built-in error there is likely to be in your results, so a 2% margin is better than a 4% margin. The higher the population size, the smaller the change in sample size needed to obtain a good margin or error. For example, if your population is somewhere between 100 000 and 1 000 000, the change in sample size required to obtain a 2% margin of error for the larger population is only 50 more people.

Note that this table assumes, in the case of a questionnaire, that you obtain answers from all people asked. If you have non-responses, you need to find extra respondents to reach the required sample size. It is also important to understand the cause of non-responses: are they due to refusal to respond (typical of street surveys); due to ineligibility to respond (can't speak good enough English or don't fit the profile you're seeking); or you haven't managed to contact the respondent (when you're making house-to-house surveys, for example).

DEPTHMAP EXERCISE
Data Analysis Using Depthmap

Files available for you to use in the exercise

FILES	DESCRIPTION	SOURCE	COPYRIGHTS
barnsbury_centre.dxf	Depthmap file containing analysed architectural layout	https://github.com/SpaceGroupUCL/Depthmap/wiki/Depthmap-Tutorials File saved from last exercise	The original CAD data copyright © Cambridge University Press 1984, reproduced here with kind permission. Original drawings by J Hanson, digitised by A Turner.

TASK

In this exercise, spatial and visual data will be used to find correlations between different visual and spatial measures. This will help understanding the nature of the measures we have learned so far. Following that we will use search for other types of data and enter these data into the Depthmap table. We will then analyse correspondences between space and other variables.

STEPS TO ANALYSE DATA IN DEPTHMAP

In this exercise you will learn to do the following activities in Depthmap in order to find correlations between space to space and vision to vision data.

1. Prepare your files

Ideally, what is required for analysis is a previously processed Depthmap file that contains some analysed spatial and visual data. We will use the file that was produced in the last workshop.

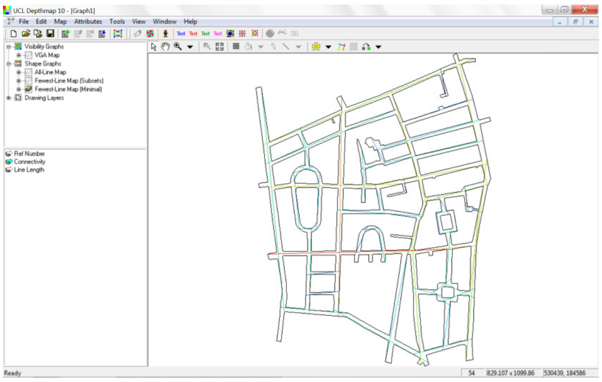
2. Prepare your map for data analysis

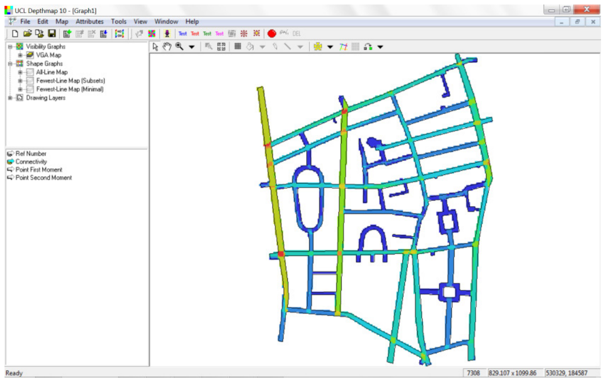
Download and import the dxf file into Depthmap. Make sure you save the file before you go further.

Choose the name "barnsbury-data.graph" and location of your file

3. Accessibility and visibility analyses

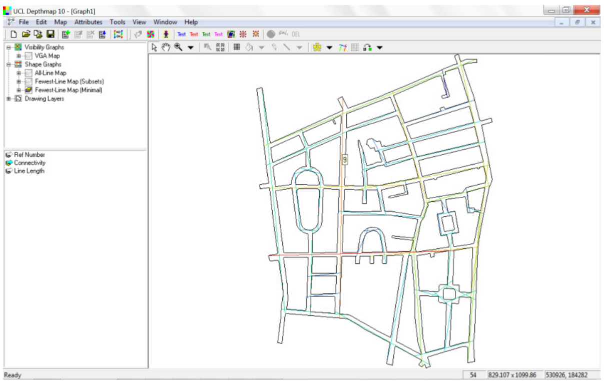
Follow the steps you have learned in the previous workshops to produce axial analysis, convex analysis and VGA analysis for the area defined in the DXF file.



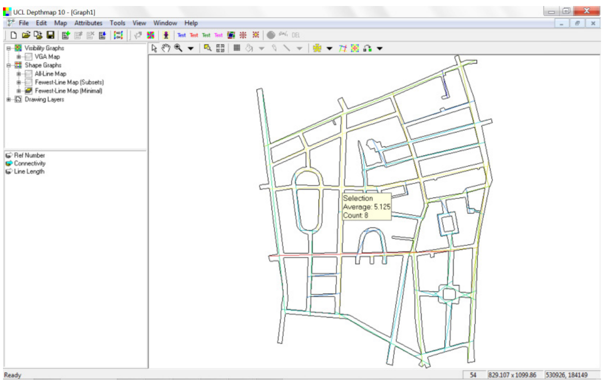


4. Looking for values rather than colours

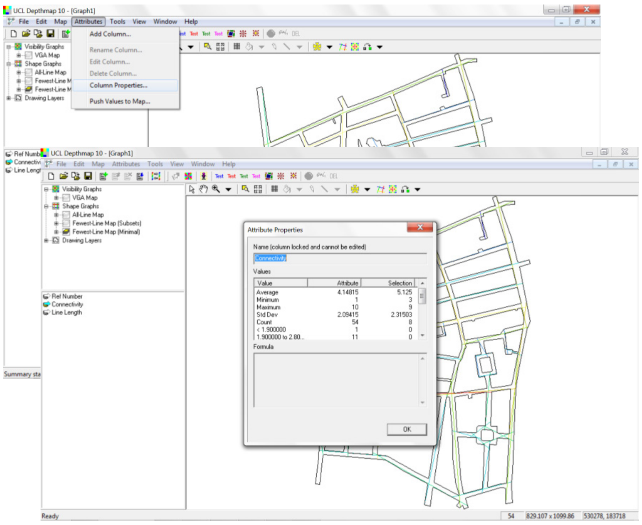
Until now we were dealing with maps that render a colour spectrum. We were also able to change the colour range to suit the representation that we need to see. Whether with spatial or visual analysis, this allowed us to find out about higher and lower values and how they distribute throughout the layout. If we are to outline models that are less inferred from these maps, we need to go further and look for values. There are several ways in which to check the values of elements.



One way is to point on one element in the layout, after making sure that the map and column for which you want to see the value of this element are active.

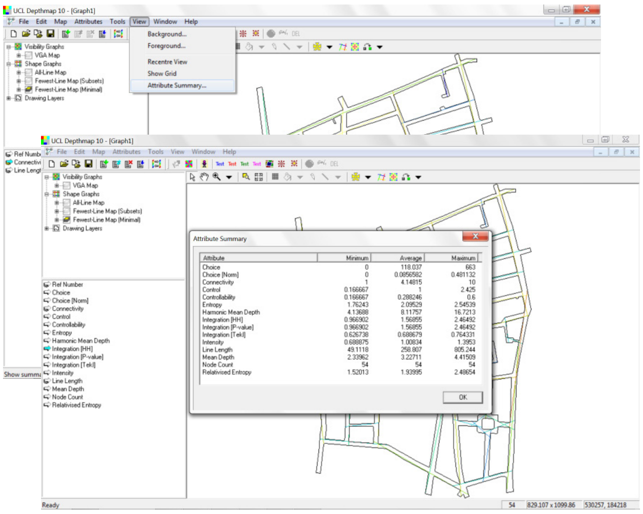


A small window will appear next to the element showing you the value of it in relation to the active column. If we select more than one element and leave the cursor on them we will be able to see the average value of these selected elements as well as the count (number of elements selected).



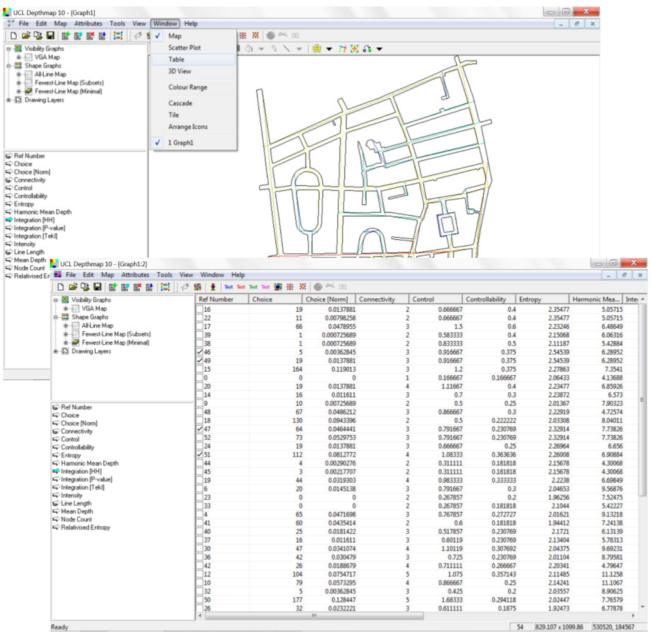
Another way of looking for values is to go to ATTRIBUTES→ COLUMN PROPERTIES.

A window will appear showing you the statistical moments of the column including average, minimum, maximum, and standard deviation as well as the count and quantiles of the range.



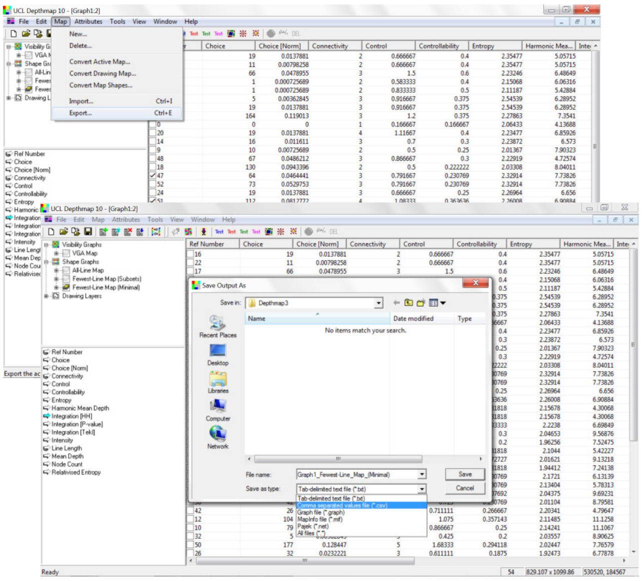
If you want to get a summary of all the attributes in the layer, you can go to VIEW→ATTRIBUTE SUMMARY.

A window will appear showing you all the columns attributes and their maximum, average and minimum values.



A more comprehensive view of all the values of columns within one map can be showed through going to WINDOW→ TABLE.

You will be able to see the elements you have selected previously as checked. The rows are associated with the ID number of each element and the columns represent the visual or spatial attribute measure of the graph configurations.



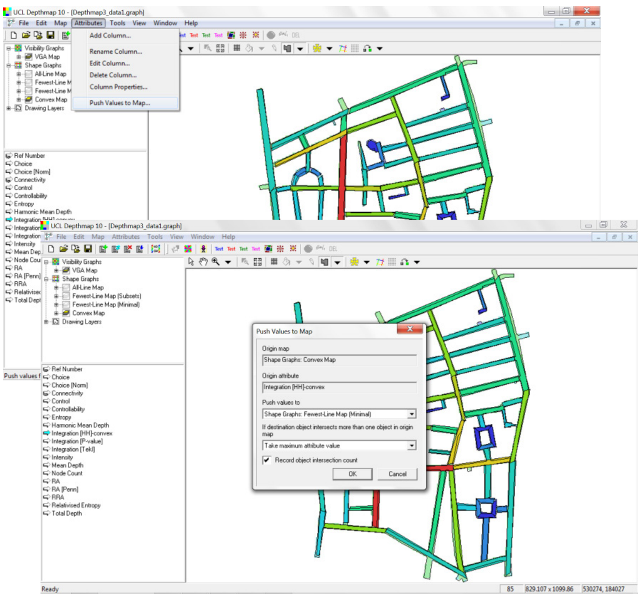
You can export this table as a txt. or as a csv. file if you intend to perform more advanced statistical analysis using specialised statistical packages.

To do that you need to go to MAP→export, and preferably choose a comma separated values file csv. format.

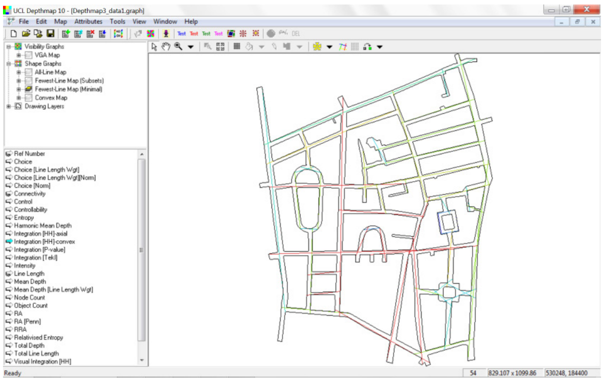
5. Pushing values

In case your convex map was active, activate your axial[15] map by making sure that the box near it looks like this . Make sure that the column integration [HH] is the active one. In case you wanted to push the values of your convex map against an axial map, you need to rename your column by write clicking it and choose rename. Change the name to integration[HH]-convex given that this column has the same name in both the axial and convex maps so if we try to merge it with an axial map for Barnsbury area it might overwrite the integration column there.

[15] Fewest-Line Map minimal if you have used the all lines method

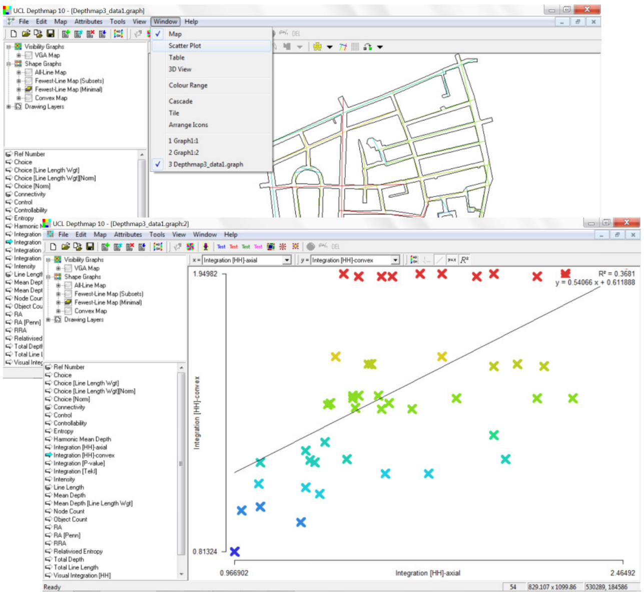


Go to ATTRIBUTES→ PUSH VALUES TO MAP. A window will appear showing you the origin map that is the convex map and origin attributes that is integration [HH]-convex. Below that you will find a drop down list of a selection of destination maps to push values to. You can choose the axial map you have created. After you have selected the destination you will see underneath different conditions of the intersection between objects from the origin map and those from the destination map. If one axial line intersects with more than one convex element we could consider either having the maximum value of the convex elements that intersect with this axial line, the minimum, the average or the total values. We have to be careful though because sometimes when we use the total values, the numbers aggregate to a very high value and might increase exponentially. For that we may need to log the column. We will learn about that later. We can tick the box that allows for recording intersection counts just to have an idea about how many objects from the origin map intersect with destination objects.



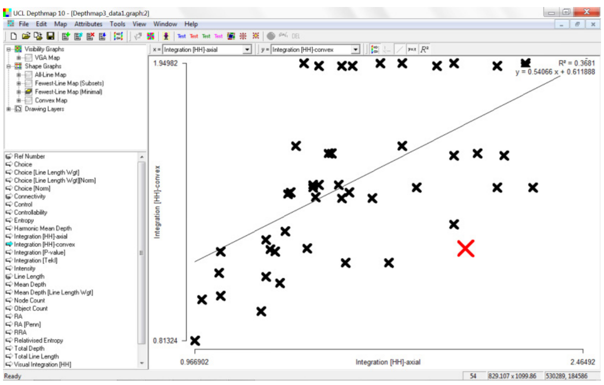
Once we have clicked OK we can go to the axial map we have chosen as a destination and find two new columns there; object count which represents the number of elements each element from the destination map intersect with in the origin map. The second column is the integration [HH]-convex from the convex analysis.

Once we had both columns within the same layer which is here the axial map, we can detect correlations -if any- between the origin attribute value and the values in the destination map.

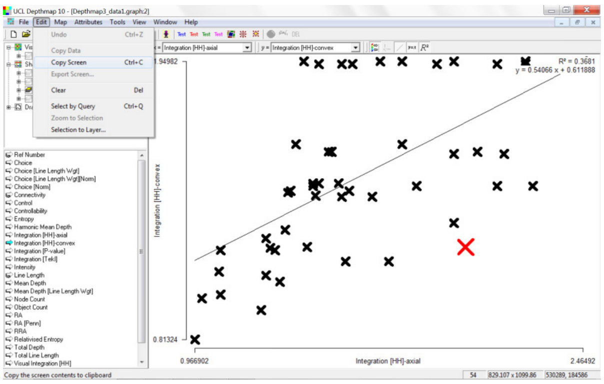


For plotting correlations go to WINDOW→SCATTER PLOT.

The window of the scatter plot will appear. You can now choose different column values to check any correlations between them. Choose the integration [HH]-convex on the x axis and the integration [HH] for the y axis.

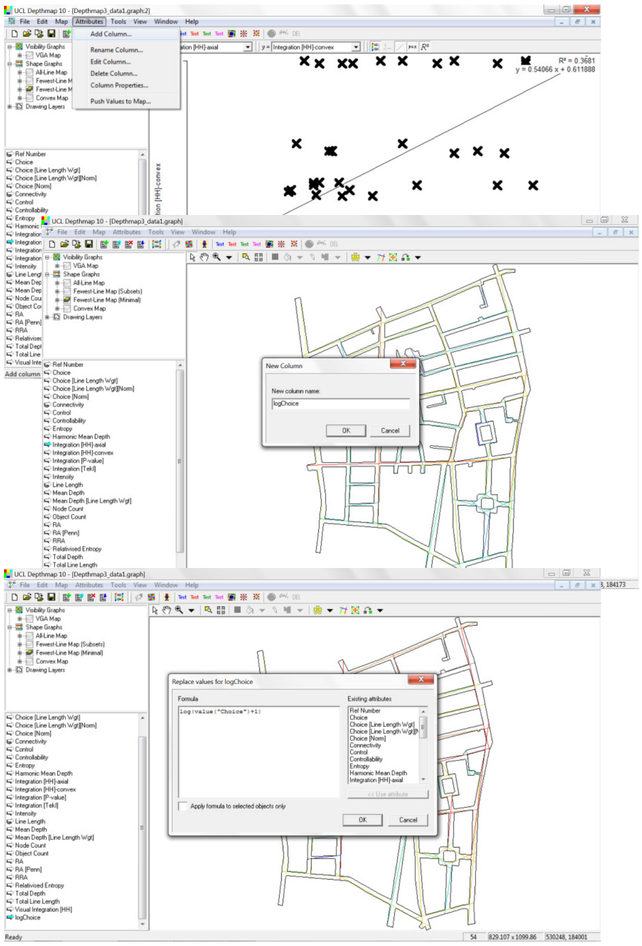


You can check the toolbars associated with the scatter plot window to see the R2 value and the formula as well as the linear correlation. The R2 value you see here is about 0.4 indicating a moderate correlation. High correlations would be 0.65 and above.



You can export the scatter Plot by going to EDIT→COPY SCREEN.

You can go on and try finding correlations between different measures. One thing that you might encounter is the strange relationship between choice and integration, looking at the maximum value of both and noticing the high difference. This can be corrected by logging the value of choice. You can do that through creating a new value and logging the formula of choice.



First go to ATTRIBUTES→ADD COLUMN.

Name your column and then go to ATTRIBUTES→EDIT COLUMN. Double click the choice attribute on the right hand side of the new window. The value will appear in the empty window.

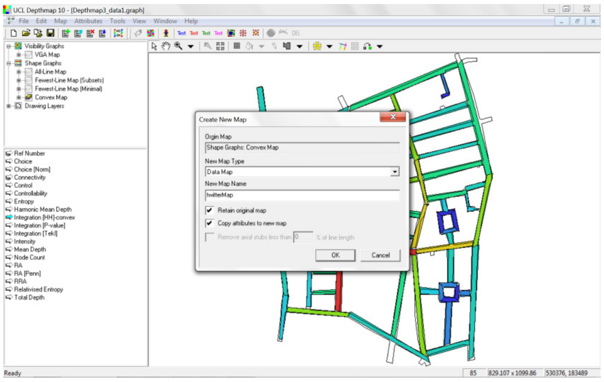
Add the term log to this value after you have enclosed it between two brackets (i. e. log(value("Choice"))).

After you have done so you may be able to see more correct reflection on the correlation between choice and integration.

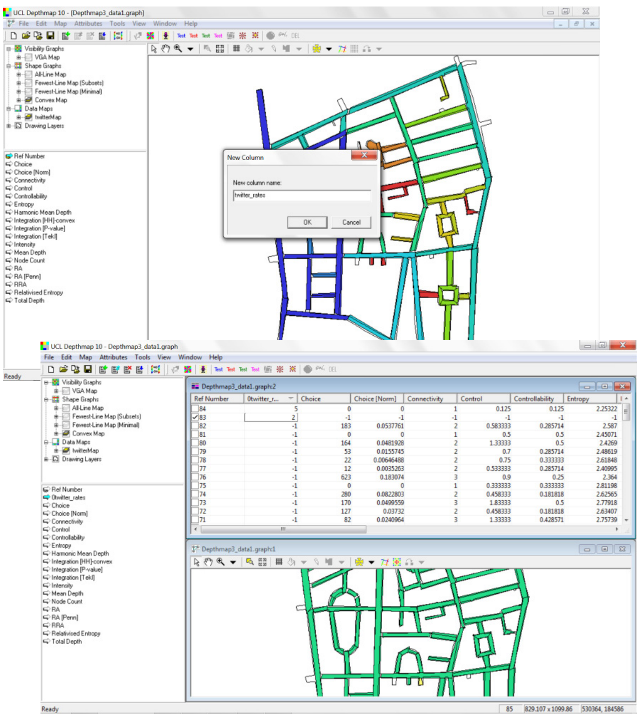
It is recommended that you save your file at this point.

6. Modelling correlations

What makes Space Syntax interesting is the established relationship between a mathematical model representing spatial structure and the corresponding social behaviour that inhabits, uses and probably formulate this spatial structure. One way to render this relationship out is through plotting scattergrams between social data and spatial data. An example for that is the relationship between occupancy rates in the real environment settings and convex integration, or gate counts with axial lines. One only has to make sure that the distribution of numbers is reasonable. With gate counts for example the counts per 5 minutes are averaged out for the day and multiplied by an hourly rate. In this case and because we did not count the number of people per gate we are going to use another type of data.



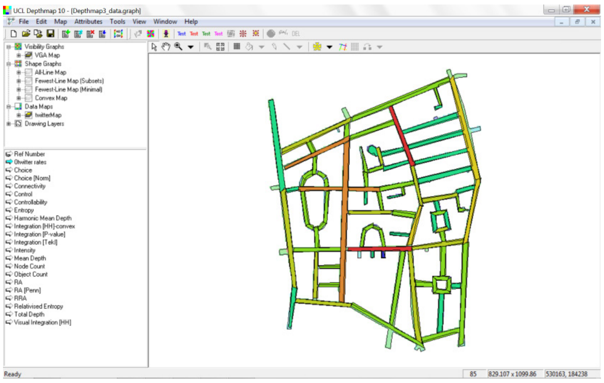
You would normally create a new data layer and record the gate data in accordance with elements you have drawn to match areas of gate counts for example. When you do that you are required to have bigger polygons that are specifically drawn to cover the gates where you have counted the number of people passing by. The polygons would intersect with at least one element in a graph network. To do that you would go to MAP→ NEW... Select data map as a map type. In our case, we could just make use of the convex map itself. Activate your convex map and go to MAP→CONVERT ACTIVE MAP. Select from the list that appear in the window the data map option. You can name it according to the type of data you are investigating (i. e. twittermap) and then check the option copy attributes to new map to have the convex map attributes copied into that layer.



Go to the new data map and make it active. Add a new column by going to ATTRIBUTES→ ADD COLUMN. Name your column 'twitter rates'.

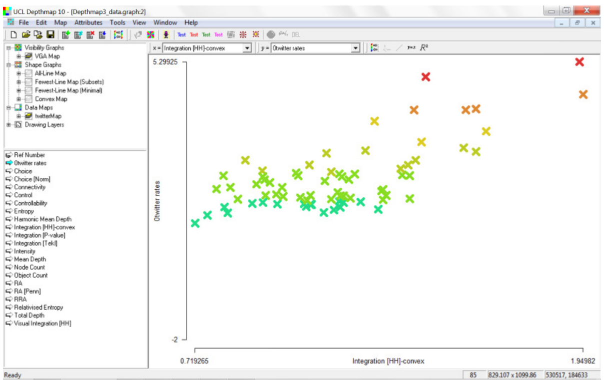
Find your analysed area on Google map and zoom in to check the names for each street. Now you will need to search for data using the web browser. Either counting the frequency of mentioning a particular street on Twitter engine or Flickr engine, looking at the number of images associated with each street on a Google map engine, looking for particular landuses or number of building blocks on Open Street Map http://www.openstreetmap.org/ (make sure to press the Map key option to get the legends for all the land uses), or look at traffic density ranks on Bing http://www.bing.com/maps/ (this option might be difficult given the small area you are covering)… There is so much Data out there!!!

Go to WINDOW and turn off the scatter plot option by clicking on it. Turn on the table and you will see the table appearing on your screen. In order for you to know which element you are selecting on the screen and its corresponding row on the table, go to WINDOW→TILE.
Using this mode you will be able to find ele-

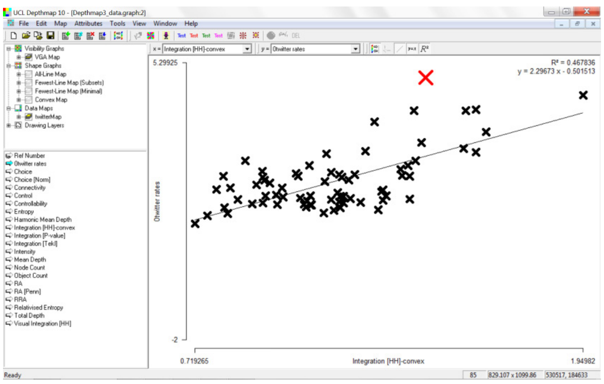


ments on the screen, and by selecting them the boxes at their rows will be checked you can edit or enter a value at a certain column by clicking on it once, type the new value, and click ENTER. At the moment each element in the new column is assigned a value of -1. You can now enter the values of twitter rates into the new column you have created. After you are done entering the values click on the twitter rate attribute you will be able to see the street spaces assigned colours according to the higher twitter rates you have entered.

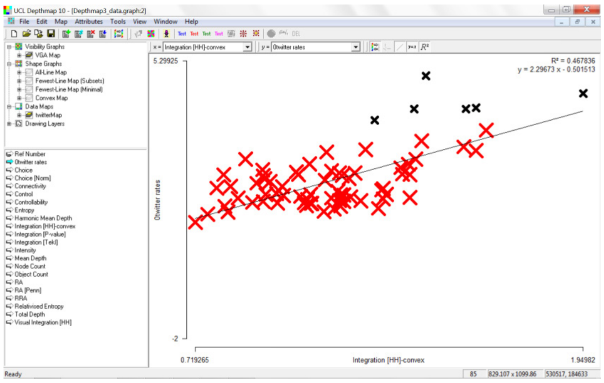
Once you have both the twitter data and spatial data columns within the same layer which is here the data map (twittermap), we can detect correlations -if any- between twitter rates and the configurational values in the spatial attributes.



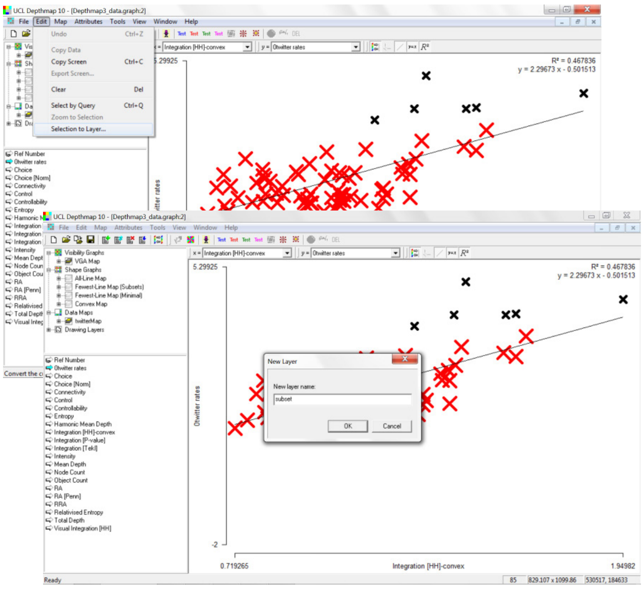
For plotting correlations go to WINDOW→SCATTER PLOT.
The window of the scatter plot will appear. You can now choose different column values for the spatial data to check any correlations between twitter data and spatial attributes. Choose the integration [HH]-convex on the x axis and the twitter rates for the y axis.



You can check the toolbars associated with the scatter plot window to see the R^2 value and the formula as well as the linear correlation. Remember that high correlations would be 0.65 and above. In our case the correlation is inverted and has a moderate correlation coefficient R^2=0.46. Remember that we have decided about the social data arbitrarily. In a real observation always try to check outliers in your correlation. You can choose elements on your screen and see them as yellow if you had the colour range on your scatter plot, otherwise if you decide to have no colours on the scatter plot they will be red.
In the scatter plot you can see some data clus-

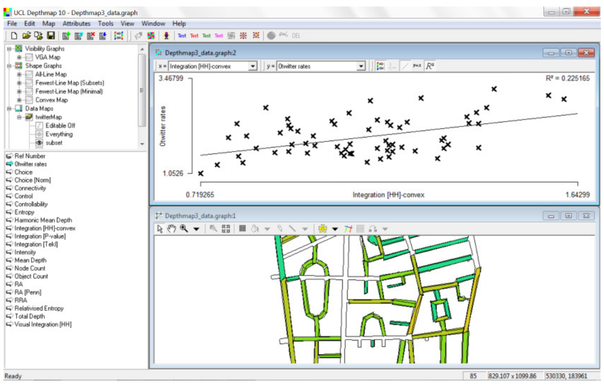


tered together and other floating away from the regression line. You might hope that these data will present a strong correlation itself with its associated spatial attributes.



In order to investigate that, you can isolate these data in a separate layer. Go to EDIT→ SELECTION TO LAYER.

Name your new layer 'correlated data' and plot it in a scatter plot against integration.



Again and to our surprise that correlation is weak R^2=0.22. Experimenting with these methods will help you understand the nature of the relationship between data and spatial variables.

Now go back to the layer 'everything'. You will be able to see the entire layer again.

You might want to consider correlations between the visual configurations and the data you have entered. To do that you need to go to the visibility graph analysis you have previously done and activate it. Also make sure that 'visual integration HH' is the active attribute. After you have done that you can go to ATTRIBUTES→PUSH VALUES TO MAP.

Select the data map you have 'twittermap' as the destination map. The method of intersection can be chosen to be average values for a change. You can check the record object intersection to see how many visibility graph nodes are intersecting or contained within each convex space in the data layer. After that click OK.

You will be able to see the visual integration HH attribute within the list of attributes in the data layer once you have activated it.

You can now check the correlation between the average integration values of the visibility graph and the data of 'twitter rates' using the scatter plot window.

In this approach you were considering the integration value of the visibility graph nodes without paying attention to the number of nodes contained within each convex space. If you want to do extra explorations and you are not convinced by the accuracy of this approach you may try to multiply the values of visual intergration by the object intersection count that is recorded within the data layer.

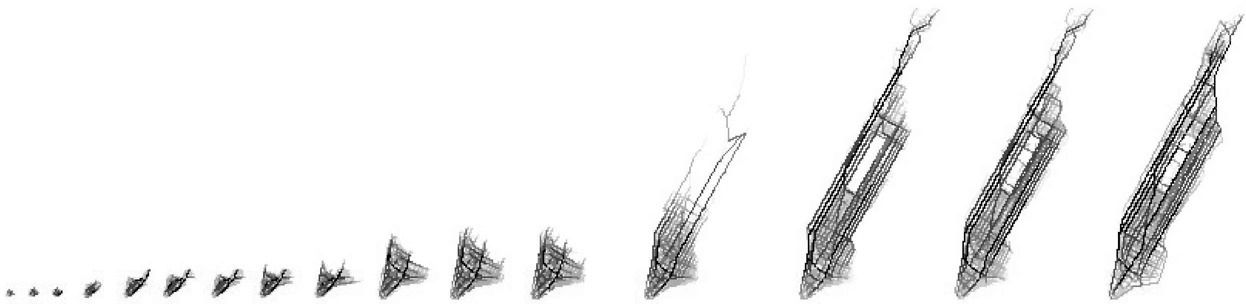
In order to do that you should go to ATTRIBUTES→EDIT COLUMN. Double click the visual integration HH attribute. You will see it in the blank window. Type * after the closing bracket and double click the object count. By doing this, you are weighting the visual integration within a convex space by the number of nodes contained within it. The formula will look like this; value("Visual Integration [HH]")*value("Object Count"). If you click OK the values of visual integration will be updated with the weighted measure.

You might want to check the correlation between axial map data and 'occupancy rates'. If you have an intuition into a possible relationship then you may follow the same steps you have gone through with the VGA data.

Of course you can always go to EDIT→EXPORT and export the map data you have into a CSV format to handle it within more advanced statistical packages. What you will find out is that data has a language of its own, the more you investigate the relationship between spatial attributes and other types of data, the more you learn about regularities and outliers and where they are more likely to occur. It is a very exciting exploration that is worth going through!

Save your file

SEGMENT ANALYSIS



THEORETICAL BACKGROUND ON SEGMENT ANALYSIS

Introduction

In this chapter, we will explain a new syntactic representation of cities which applies to both topological and geometric configurations of space. This representation is on the level of street segments, considering their topological, metric and angular connections. Along with other software, UCL Depthmap has the capacity to produce different types of segment analysis using different radii. We are going to learn about segment analysis, what it can do, how powerful it is as a tool for predicting social and economic activity, the different scales of measurement and graph distance associated with it. We are also going to list the reasons to shift from axial analysis to segment analysis, and how the measurements differ in this case. We will highlight the most powerful tool for measuring accessibility in street networks; that is angular depth with metric radius. Using this type of graph representation, we will calculate integration and choice to measure accessibility and compare configurational properties of space with observed urban activity. These two measures; integration and choice, will be devised to identify to-movement and through-movement potentials. Other measures such as metric and topological analysis of segment maps will be explained in later chapter.

Segment maps: A linear representation of urban spaces

In previous chapters, we explained how an axial map representation of city spaces might help forecasting potential movement activity in real cities, however, axial lines appear to be less helpful when trying to detect semi-continuous lines in the system. This was particularly the case with cities that have a uniform structure with very little disruptions and with smooth linear streets that cross the regular streets diagonally. An example for that is Broadway in Manhattan. In such cases, a different representation of the spatial structure was found necessary (Dalton, 2001). Such a representation was required to detect these linear or semi-linear connections in the urban structure and therefore had to use angular rather than topological configurations. For this purpose, a finer grained representation was introduced to the Space Syntax model considering street segments as the elementary components of street networks. Each street segment is defined by the interjunction between two intersection points. Segments have geometric properties marking the cumulative angle between each pair of intersecting streets. One of the most useful configurational methods of analysis is that of angular depth which outlines the shortest angular journeys through the spatial network. Angular analysis was found to correspond well with spatial navigation and wayfinding, since users are likely to minimise cognitive distance as they walk through a foreign environment (Hillier & Iida, 2005).

Angular segment analysis with metric radius

As mentioned before, angular analysis, particularly the one constrained by metric radius[16], was found to be instrumental in detecting major to and through-movement routes in a street network. Research suggests that a metric radius is especially needed to avoid the edge effect of the boundary that define a pre-selected cluster of streets (Turner, 2001). The selection of the boundary may cause distortions in the values of graph distance.

[16] A metric radius is the physical network distance within which angular turns might be calculated for each segment street element.

It is important to emphasise that the metric radius of the measure refers to the metric distance from each segment along all the available streets and roads from that segment up to the radius distance. Following this definition, radius 'n' means that each segment is related to every other segment in a city without any radius restriction. This pattern changes as we reduce the radius of the measure. So if we are to consider a metric radius as a "cookie cutter" in a network of nodes and connections, resembling a segment map with segments and points of intersections, the system will be analysed around that particular node or segment. In this case, radius 400 metres (approximately 5 minutes walking distance) will only calculate angular turns of all nodes within 400m from the current node, any nodes beyond that radius will not be calculated. This means that the system will only identify the local relationships between segment elements within 400 metres along the neighbouring segment lines starting from each one of them.

Deciding about the minimum and maximum radius in an analysis is not restricted to certain norms. Before beginning an analysis a set of fundamental research questions need to be posed depending on the nature of investigation: What radius measure would best correlate with block size parameters, segment length, land values, Twitter activity, pollution rates or observed patterns of pedestrian and vehicular movement within a certain urban area? Local movement is normally best represented by a local radius measure – 800 metres which is equivalent to 10 minutes walk. Market areas with finer scale grid pattern are better represented at a lower radius such as 400metres. Higher radius measures are then needed to represent vehicular movement flows.

The principle of angular depth calculation in segment analysis

A segment map is a broken representation of an axial map, where segments are the inter-junction lines between points of intersection in an axial map (stubs can be considered if long enough). Angular depth calculation in segment analysis takes a different form compared to that of axial analysis. Angular segment depth is calculated by adding up the weighted values of the edges, where each edge is weighted by the angle of connection. To make it more clear, the intersection of two segments at an angle of incidence 47±, which might be approximated to 45± degrees, might have a weight of 0.5. If one of these segments is intersecting with a different segment at 107± degrees, then it will have a weight of 1. If these three segment elements are connected in the same direction then the depth between these street elements is the sum of their weighted angular intersections, that is; 0.5 +1=1.5. This angular sum can be considered to be "the cost of a putative journey through the graph", and from it a "shortest path" is one that presents the least angular cost from one segment to all others in a street network, (Turner, 2001). The turn angle is always regarded as positive and the calculation accounts only for directional movement, meaning that, the point where one leaves the segment, a "forward" link should be in the same direction as the point at which one has previously arrived at the segment's "back" links.

Tulip Analysis

In principle, Tulip analysis is set to approximate angular turns to a segmented circle. It calls this an 8 bin tulip analysis in which 360° is equivalent to 32bins. UCL Depthmap gives the ability to segment to any degree within the range 4 to 1024 bins which in a way approximates full angular analysis, whilst also improving on the speed of computation. The following example elucidates how Tulip analysis might be used to approximate values;

- a turn of less than 22.5± might be assigned zero value

- In the same way, a turn of 97:5± could be rounded to 90±, and assigned a value of 1.

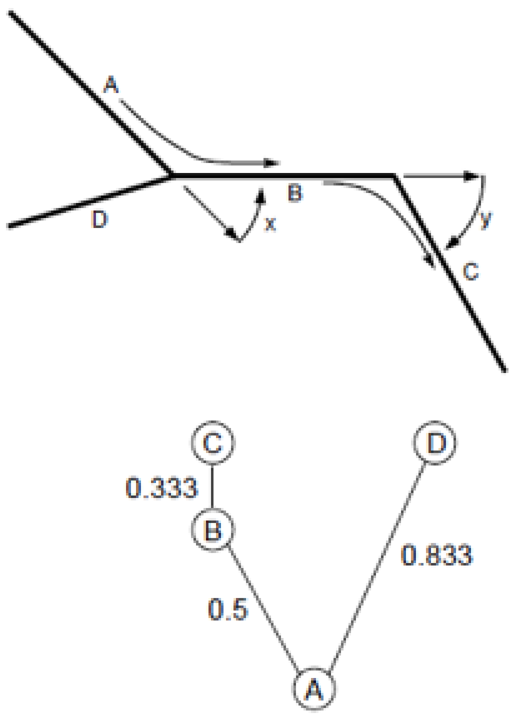
[17] See appendix 2. For further description about angular segment analysis measures please refer to Depthmap 4: A Researcher's Handbook (see references)

Angular Segment Analysis Measures[17]

1. Angular Connectivity

The segment analysis measure of angular connectivity is considered to be the cumulative turn angle to other lines. The turn angle is weighted so that a 180°±,angle will be equivalent to a cumulative weight of 2 and an angle of 45°±, will correspond to a cumulative weight of 0.5. If we look at the example in figure 9.1 we see that the calculation of the measure for a segment B is made through adding angle x to angle y;

Angular connectivity B= x + y = 0.333 +0.5



[18] Diagram source: Turner, A. (2005) Could A Road-centre Line Be An Axial Line In Disguise?

Figure 9.1 . An example of a segment map and its associated graph[18].

2. Step Depth

Step depth follows the shortest angular path from the selected segment to all other segments within the system. The weighting used in the angular scale considers 1 step as a 90± angle. Angles are cumulative. The depth from segment A to segment B in figure 1 is 0.5 (a turn of 45o).

3. Node Count

Node count is the number of segments encountered on the route from the current segment to all others. In the case of figure 1 we consider node count (NC) to be 3 because the shortest angular path goes through three segments.

4. Total Angular Depth

Total angular depth is the cumulative total of the shortest angular paths to all segments. In the case of segment 'A' in figure 1, the angular total depth is;

TD 'A' = (B)0.5+(C)0.833+(D)0.833= 2.166

5. Mean Depth

The angular mean depth value for a line is the sum of the shortest angular paths divided by the sum of all angular intersections in the system rather than the number of lines in the system. Mean depth in general terms is indicative to how deep or shallow a node is in relation to the rest of the graph, a measure defined as centrality. However, Mean depth seems to have several problematic issues with regards to its implementation and verification in angular segment analysis. On a small radius such as radius 500 metres, angular mean depth is a meaningless measure. It will simply approximate node count. On radius n, node count has a constant value, because we are simply considering all the nodes (segments) in the system. In this case, angular mean depth will be proportional to angular total depth. In the example illustrated in figure 9.1, angular mean depth for the segment 'A' is calculated in the following way;

MD 'A'= TD 'A'/NC = ((B)0.5+(C)0.833+(D)0.833)/3 = 0.722

6. Relative Asymmetry RA and Real Relative Asymmetry RRA

RA and RRA in axial analysis have no corresponding methods of calculation in angular segment analysis. The problem with RRA is basically that there was no method of relativisation for the type of fractional numbers that result from weighting the angular values in the graph. Relativisation is normally needed to compare systems and sometimes different parts of the same system which contains in both cases different numbers of elements. A solution for the relativisation problem was proposed recently (Hillier et al, 2012). This solution is explained in the last section.

7. Integration measure

Integration in angular segment analysis is a good predictor of the potentials for each segment within a metric radius to be a highly desired destination. In other words, the measure forecasts the to-movement potentials for each segment when measuring on all the shortest angular paths in the system from all origins to all destinations.

Hillier's integration measure

Integration = (NC * NC) / TD

Integration for angular segment analysis = NC/MD = NC/(TD/ND) = NC * NC/ TD

Some approximations of the measure in special radius types;

Integration radius n = 1/Angular total depth, because node count is a constant in this case.

Integration low radius (radius 400 metres) ≈ NC

8. Choice measure

Choice (betweeness) is calculated automatically in Depthmap for different radii. It basically calculates the potentials for each segment element to be selected by pedestrians as the shortest path (when considering a small radius) or selected by drivers (when considering a large radius) or both. So choice signifies the through-movement potential of a segment in a spatial system. The calculation is defined according to Turner (2001) as the following, "for all pairs of possible origin and destination locations, shortest path routes from one to other are constructed. Whenever a node is passed through on a path from origin to destination, its choice value is incremented." In Depthmap, when calculating each shortest angular path within the system, a value of '1' is assigned to every segment in the route from any origin to any destination. If the shortest paths go through an element twice the calculation of angular choice records the value '2' for that element. This adding up continues until all shortest angular routes are identified and calculated in the system. Then the system identifies randomly all the equivalent shortest angular paths and eliminates one of each pairs.

Note that, both integration and choice could be combined in one measure. This makes it possible to find the segments in a network which serve as both a potential destination and route of movement. This measure will then narrow the focus on fewer and more significant elements within the system that combine the attributes of being a potentially desired destination and at the same time a desired route for movement.

9. Weighting by segment length

Depthmap gives the possibility of weighting segment analysis to different measures. One of the most valuable weighting methods is to weight by segment length. Mainly because longer segments are likely to have more blocks and entrances adjacent to them on each side leading consequently to higher rates of movement activity. This argument is valid for pedestrian movement and is more likely to apply to smaller radius of analysis. When considering vehicular movment, we might anticipate that drivers would preferentially choose to drive straight forward without taking many turns, hence longer lines are more likely to afford higher speeds. Longer street lines might characteristically define higher speed motorways, where journeys are rarely disrupted by road junctions and traffic lights. Pedestrian and vehicular journeys are, therefore, more likely to pick up longer segments if they fall within a shortest angular path from all origins to all destinations. The arguments for pedestrians or vehicles to choose the shortest path with longer lines would all depend on the radius of analysis whether small or large.

10. Normalising choice and integration

Recently, new advancement on angular analysis was introduced by Hillier et al (2012); that is the normalisation of angular choice and integration measures (see appendix 2). The purpose was to enable the comparison between systems of different sizes. It was basically necessary to introduce new normalisation methods to angular distance in a graph, since it was not possible to use the diamond-type of value (D-value) that was initially used to normalise topological distance in axial and convex graphs. The normalisation of choice was motivated by acknowledging the relationship between high choice and high total depth, that is the more segregated the system is, the higher choice values are. Choice was seen therefore as a necessary condition to overcome the cost of segregation in the street network. This is a cost-benefit principle that was introduced by Tao Yang in Hillier et al (2012). The new normalised angular choice measure was named as NACH;

$$NACH = \log CH+1/\log TD+3$$

In Hillier et al experiments, NACH has proven to be independent from the size of cities – quantified in number of segments- but was found to correspond well with simple segment connectivity. Integration had a simpler explanation, where the system is being compared to the urban average. The result is a normalised angular integration measure (NAIN) computed as follows;

$$NAIN = NC^{1.2}/TD$$

These two methods of normalisations have immense advantages, making it easier to expose the inner structure of urban form, and making it possible to compare street configurations in different cities and in different locations within a city. In principle, it is possible to characterise cities based on their maximum and mean values of integration and choice, the maximum values defining the foreground structure of the grid and the mean values defining the background structure. When comparing different cities with regards to their maximum and mean values, we find that higher values are always indicative to how structured a city is, whilst mean values are indicative to how grid-like a city is, but are not determinant of how structured a city is. Similar to the usual definition of integration, maximum and mean values of NAIN are related to the ease of accessibility in the street network. Mean values of NACH are associated with how continuous a structure is in relation to the background, while maximum values of NACH are representative of how deformed or interrupted is the foreground structure of the grid. The performance of these measures vary from city to city. The characteristic values of these measures for each city are thought to tell something about the distinctive typologies that cities share. They might also be indicative to how cities emerge in time, whether through deformations on a regular grid pattern like Manhattan or through a bottom up mechanisms, the case with London and Tokyo.

The initial testing of the measures -as explained in Hillier et al (2012)- proved to be very effective. However, few issues have arisen in some cases where the application of the measures on the local scale in areas that are less urbanised was rendering out some erroneous results. To deal with that, it is recommended that fully urbanised areas and periurban regions should be analysed separately. Another issue was emerging when dealing with Road-centre line maps, where multiple segments on the same line were adding up to the values of choice, hence distorting the results. For that, an automated procedure was developed at Space Syntax Ltd. to eliminate this effect. This problem can also be solved by manually deleting the extra lines. It is also advised, that stubs up to 40% should be cleared from segment maps before running the analysis. This is to ensure that no unnecessary depth is introduced to the system as that might increase segregation and distort the values of normalised choice.

DEPTHMAP EXERCISE
Segment Analysis Using Depthmap

Files available for you to use in the exercise

FILES	DESCRIPTION	SOURCE	COPYRIGHTS
cityofLondon.dxf	Cad drawing file containing intersecting series of line elements	http://moodle.ucl.ac.uk/	London original map data copyright © UCL.

Task

The main task in this exercise is to get from an axial map, to segment map[16], to some analytic measures of the spatial structure of urban environments.

[16] Do not convert your map directly to a segment map! You must make an axial map first to preserve the links/unlinks if there are any embedded in the file.

Steps to perform axial and segment analysis in Depthmap

In this exercise you will learn to do the following activities in Depthmap in order to do segment analysis from axial lines data.

1. Download your files

Go to http://moodle.ucl.ac.uk/mod/resource/view.php?id=645834

Follow the link

UCLMoodle → TMSARCSAAS01 → Resources → PoAD_Depthmap Workshops → workshop4

and download the file cityofLondon.dxf from the website onto your desktop

Prepare your axial map

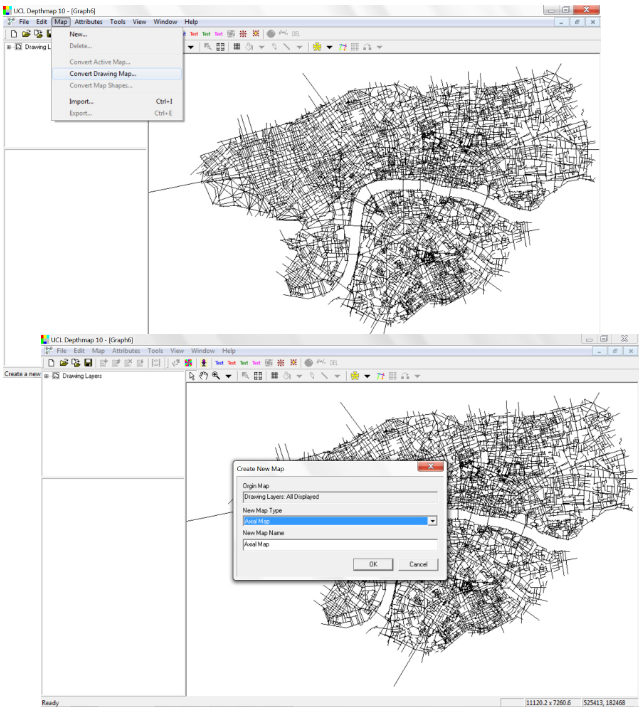
Create a new file: Go to FILE---NEW. This gives a blank page.

Save the file you are using: FILE---SAVE

Choose the name and location of your file

Import the axial map into Depthmap: go to MAP--- IMPORT--- look in your Desktop for a file titled cityofLondon.dxf. Choose the DXF file and click import.
Now you will have the file imported into your Depthmap file as a drawing layer.

2. Axial analysis



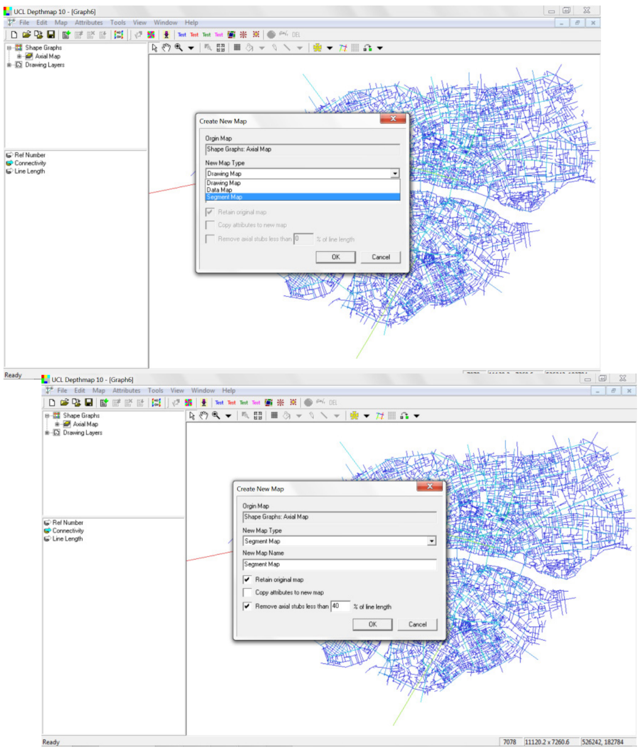
Convert your drawing map into an axial map. To do that, go to MAP menu and choose CONVERT DRAWING MAP.

A pop up window will appear. Under the NEW MAP TYPE choose AXIAL MAP.

You could change the map name under NEW MAP NAME. The default is AXIAL MAP and it will number it if you have more than one axial map.

Once you have done that you will be able to see the basic attributes of an axial map, which are; REFERENCE NUMBER, CONNECTIVITY, LINE LENGTH.

3. Creating a segment map



Convert your axial map to a segment map. You can do this by going to MAP menu again and choose CONVERT ACTIVE MAP.

A pop up window will appear. Select SEGMENT MAP from the NEW MAP TYPE menu.

You could change the map name under NEW MAP NAME. The default is SEGMENT MAP and it will number it if you have more than one segment map.

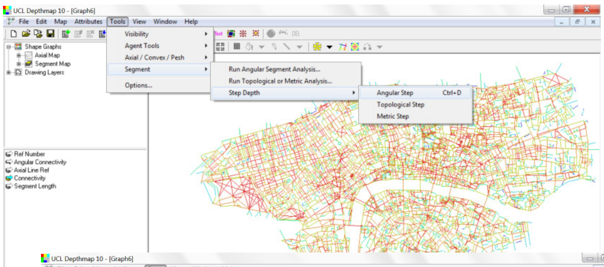
From the ANALYSIS TYPE choose the option to REMOVE AXIAL STUBS LESS THAN 25% OF LINE LENGTH (40% is the default if you choose this option)[17].

[17] You could change this value in a way that suits your map interpretation. This often depends on the length of axial lines you have because you don't want to remove long axial stubs as that might lead to missing important information in the map you have.

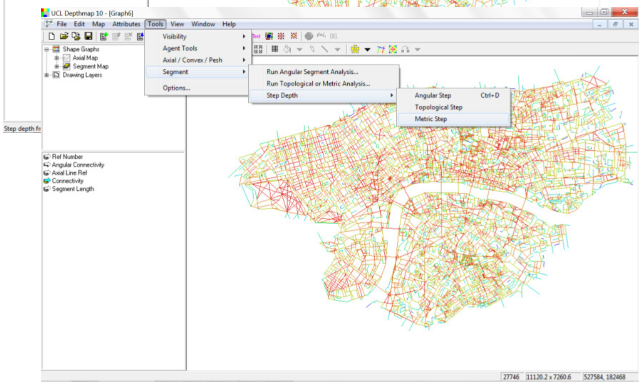
4. Calculating different types of segment step depth

Choose the SELECT icon from the tool bar on top of the MAP window.

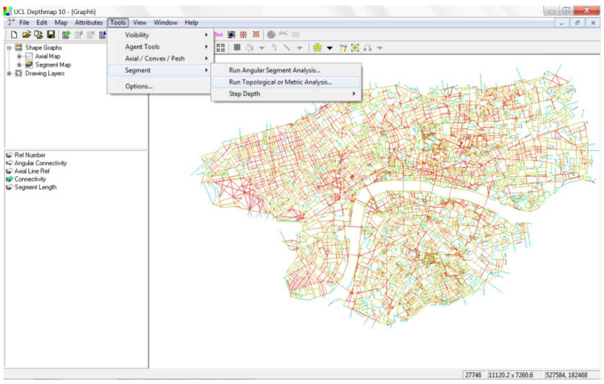
Select one element from the segment map.



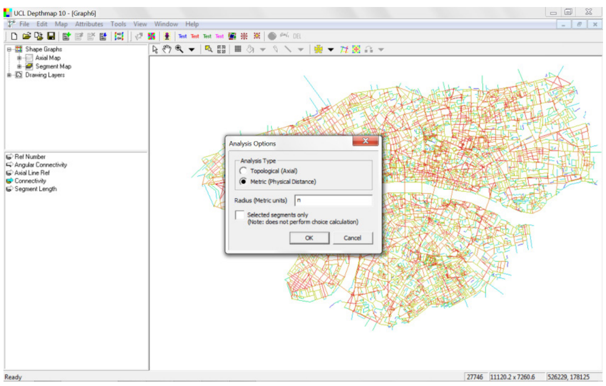
Go to TOOLS ---SEGMENT--- STEP DEPTH --- ANGULAR STEP.



To explore other sorts of step depth go to TOOLS --- SEGMENT --- STEP DEPTH---TOPOLOGICAL STEP. Also try out TOOLS --- SEGMENT --- STEP DEPTH --- METRIC STEP.



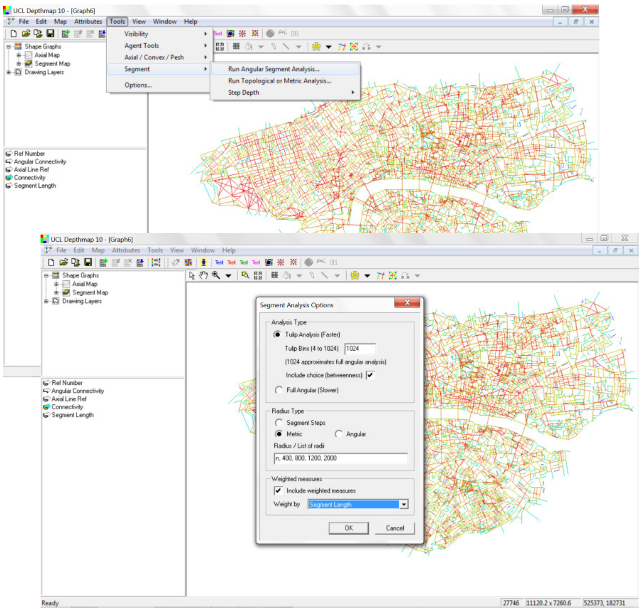
To limit the analysis by metric radius click anywhere in the map window to remove the selection (this step is not vital to execute the analysis). Then go to TOOLS --- SEGMENT --- RUN TOPOLOGICAL OR METRIC ANALYSIS.



A pop up window will appear you could select the type of analysis you want to perform by either choosing the analysis type (either TOPOLOGICAL or METRIC analysis) and then insert the metric radii you are interested in such as (n or 400 or 800 or 1200m).

5. Segment analysis[18]

[18] Most description of segment analysis is rather technical, but it would make sense to read the papers about it: Hillier and Iida (2005) and Turner (2007). For some historical perspective, you might also like to look at Dalton et al. (2003), although note that Dalton et al.'s fractional analysis differs in detail from the later methods.



Run the segment analysis: by going to TOOLS---SEGMENT---RUN SEGMENT ANALYSIS.

A pop up window will appear showing SEGMENT ANALYSIS OPTIONS.

Choose the default TULIP ANALYSIS rather than FULL ANGULAR. Tulip analysis does everything that full angular does and much more. Also ensure you select INCLUDE CHOICE (BETWEENNESS).

For RADIUS TYPE, change to METRIC, and select a range of suitable radii to measure. Everything at this stage hinges on whether or not you made sure you scaled your map correctly in metres. If you did, then a list of sensible radii might be: n,250,500,750,1000,1250,1500,1750,2000,2500, 3000,4000,5000 with a comma but no gap between each (no comma at the end) (another sensible option will be (n,200,400,800,1200,1600,2000,2400,3200 – it is up to you to decide about the most suitable radius[19]).

[19] The minimum and maximum radii chosen will depend upon the grid dimensions and spacing.
Also make sure that you tick the box marked INCLUDE WEIGHTED MEASURES and select weight by SEGMENT LENGTH from the drop-down menu.

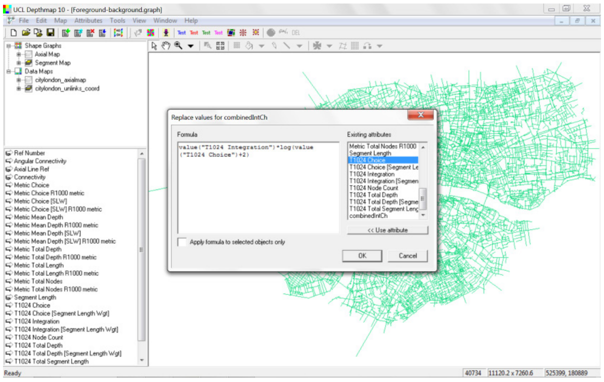
Click OK and the analysis will run. A box will tell you how long it will take.

Once the analysis is finished you will have a series of measures the most important of which is T1024 CHOICE. Note that this is different from axial choice measure.

Ignore for the time being those measures with 'Norm', and 'Segment Length Weighted' (and the combination of the two).

You will be able to see an integration measure.

6. Combining integration and choice



You can create a combined measure of integration and choice by multiplying one by the other. To do this go to ATTRIBUTES and select ADD COLUMN from the menu.

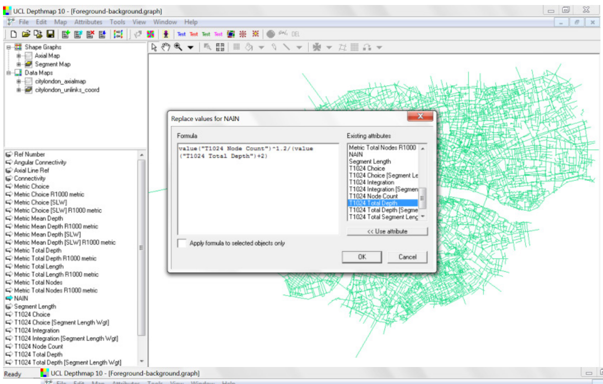
A window will appear in which you will provide the NEW COLUMN NAME. Then you have to edit the column (either using EDIT COLUMN from the ATTRIBUTES menu, or right clicking on the new column and choose EDIT). In the FORMULA part fill in the combined measure formula, where XXX is the radius you want the integration measure for:

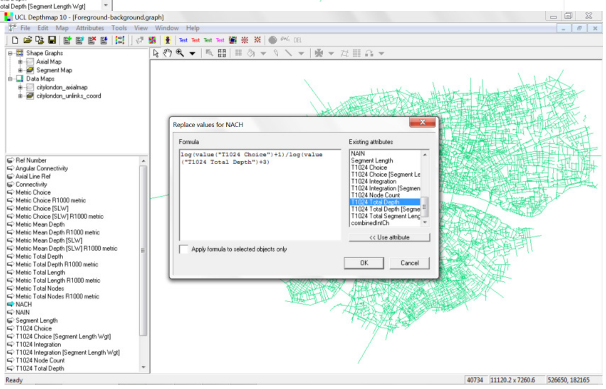
(value(“T1024 Integration RXXX metric”))*(log(value(“T1024 Choice RXXX metric”)+2)).

7. Calculating normalised measures of integration and choice

You can create a normalised measure of integration or choice by creating new columns for each measure which we will name as NAIN, NACH respectively. To do this go to ATTRIBUTES and select ADD COLUMN from the menu.

A window will appear in which you will provide the NEW COLUMN NAME. Type NAIN for normalised integration and NACH for normalised choice





Then you have to edit the column (either using EDIT COLUMN from the ATTRIBUTES menu, or right clicking on the new column and choose EDIT). In the FORMULA part fill in the normalisation formula for each measure separately, where XXX is the metric radius for each measure:

NAIN

value(“T1024 Node Count RXXX metric”)^ 1.2 / (value(“T1024 Total Depth RXXX metric”)+2)

NACH

log(value(“T1024 Choice RXXX metric”)+1)/ log(value(“T1024 Total Depth RXXX metric”)+3)

Notes

NOTE 01

When you need to draw axial lines data using map image files;

You may use whichever drawing package you prefer to create a vector drawing of the axial map to import into Depthmap, however, MapInfo or other GIS packages are strongly preferred as it will allow you to register your map images to the OS national grid, and thus link your axial map to other axial maps.

If you are using MapInfo to produce an axial map out of a map image file, consider how to register the image. That is, at the moment, the image is simply pixels on the screen, but in fact, each pixel corresponds to a location on the UK national grid, and this is the preferred format. To register it, you will need to download contemporary vector map data from OS to which to register the map. Please consult your GIS lectures for how to register images within MapInfo.

Once your image is registered, you should start drawing the axial map. Make sure that you use a new layer within MapInfo for your axial map.

If you are unable to register your image, at the very least set the correct scale within your GIS or CAD package. If OS national grid units are not available, use metres instead.

NOTE 02

In order to import the axial lines drawing file you need to export it from the drawing package (CAD, GIS) you have used to draw the lines. From CAD you can export a DXF file; from MapInfo it is probably easiest to export a MIF/MID combination (although you may also export DXF from MapInfo if you prefer).

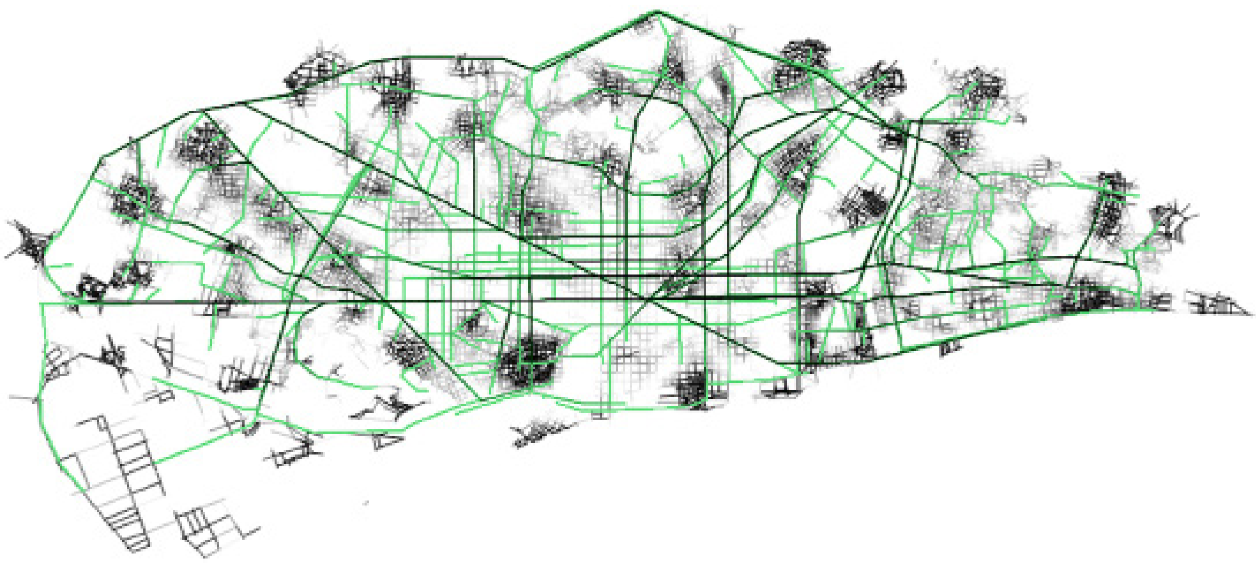
Always Check the integrity of your axial map before piling straight into the analysis of your axial map, but wait! Check that your axial lines are properly connected to each other. You can go through the map looking at the number of connections (just hover the mouse over a line), or check all lines are connected by performing a 'step depth' calculation. Both of these methods can be found in the Depthmap axial analysis tutorial at UCL Bartlett website. If you find lines that are unconnected, that should be, fix the map either within Depthmap or MapInfo(if you have imported a MapInfo file), once again, see the tutorial. Actually edit the lines rather than using the 'link' tool. You may want to export the edited map as a MapInfo MIF/MID file if you make significant changes to your original map.

In rare circumstances, you may need to unlink lines where it is not possible to get from road to another – for example, if there is a bridge. Go through the axial analysis tutorial to find out how to unlink lines, and unlink where necessary.

NOTE 03

if you don't have a proper metric (scale) on your map, then Depthmap will allow you to set integer radii i.e. 1,2,3…..n where 1 is a single one of the units in which the map was drawn

ADVANCED AXIAL AND SEGMENT ANALYSIS



THEORETICAL BACKGROUND ON ADVANCED AXIAL AND SEGMENT ANALYSIS
Foreground vs. Background analysis

Introduction

This chapter is aimed to explain some of the aspects of metric analysis in cities and how it helps to spot localities with homogeneous identity in terms of the scale of grid structure. These localities appear as patchwork patterns in segment maps. Along with these local metric signature of neighbourhoods there seems to be an associated global structure which can only be identified by rendering its topo-geometric attributes. We will introduce these two models of spatiotemporal segment maps. While a patchwork pattern can be approximated using the metric depth tool in UCL Depthmap, the top-geometric structure of the grid needs more experimentation on how to expose it. Generally, an angular measure of integration or choice will do, however, this can vary according to the type of grid and area that need to be represented. There is still not much to say about how these studies can be beneficial. Yet, they do tend to help us acquire a better understanding of cities and their generative mechanisms.

What are the main components of cities that distinguish the global structure from the local structure?

Cities can be represented by large graph networks where linear representations of street spaces might be regarded as nodes and where intersections between street lines are denoted as links. If we consider street interjunctions as a finer level of representation of street spaces, we might derive a richer description of urban space; that is a segment map. Segment maps might be seen as to reduce the layout complexity of streets, by accounting for the linear elements that make its structure. An analysis of the topological and geometric properties of the segmental structure of streets is likely to expose some of the processes that led to the formation of urban grid, and the role of different economic and social forces in shaping urban form. The syntactic model explains all these processes in a synchronic representation, whilst also acknowledging how simple local dynamics might generate global structures that are similar to those of cities. A proposed description of these local dynamics is that of "Centrality and Extension" identified by Hillier (1996) as: Don't block longer alignments if you can block shorter ones. By implementing this rule what we get is a large aggregate structure of shorter lines intersecting with near right angles and longer lines continuing to intersect with each others with smaller angles to connect the local structures of the parts. The patches of uniform shorter lines nest in-between the global semi-linear connections. The clustering of local structures and the global pattern of major road infrastructure can be identified through rendering the metric and angular properties of streets networks.

On defining the global structures or the foreground layer of street networks, the original syntactic axial model presented some deficiencies, hence there was a need for a methodological intervention. Previous studies by Figueiredo and Amorim (2004, 2005) recognised that axial analysis cannot identify continuous linearity in the system. In response to this problem, Figueiredo and Amorim suggested "continuity lines" as a method to unify the long axial lines that intersect with smaller angles and hence consider these unified linear representations as single elements when computing different configurational measures of Space Syntax. In this way, "continuity lines" can be considered as to represent a global structure highlighting roads that are likely to afford higher movement flows due to their configurational properties. The issues presented by semi-continuous streets were also discussed by Dalton (2001), who proposed fractional analysis as to recognise angular graph distance in calculating depth in urban layouts. Through the use of fractional analysis, it was possible to highlight the role of Broadway in the grid-iron street network of Manhattan. Another contribution was made by Dalton (2007) to empirically define local structures, in a dedicated effort to find some quantitative description of urban identity. In his approach, Dalton plots the values of point synergy and point intelligibility of axial lines and accordingly reaches a form of patchworks map that shows fuzzy boundaries of neighbourhood vicinities. Synergy was recognised by Hillier (1996) as the relationship between local and global integration highlighting some underlying relationship between the parts and the whole in cities. Intelligibility is similarly relating a local measure such as connectivity with the measure of integration in an axial map, and in this way the measure gives an idea about how intelligible and permeable a space is for users.

More recent work by Hillier et. al. (2009) revealed an interesting manifestation of both the local and global patterns of grid structures. The local to be highlighted as patchworks of metrically similar areas, and the global to be represented by semi-continuous lines in the grid highlighting shortest paths between all origins and destinations in an urban system. The metric patchworks serve as a background structure and correspond to some extent with known localities in politically-defined neighbourhood areas. The metric patchwork patterns are highly sensitive to the scale of measurement. The longer continuities serve as a foreground layer and stand for the shortest connections. They very often match busy streets in the urban fabric.

Background Analysis: Producing patchwork maps

Patchwork maps are interesting manifestations of the metric density of urban structures. They look interesting and promising as they appear to mark out distinct areas in cities Hillier et. al. (2009). The clustering of patchwork patterns is thought to represent the spatial signature of dynamic local processes of attachment, pruning and diffusion (Al_Sayed, 2013). The meaning of metric analysis and its relationship to angular analysis are very much dependent on scale (figure 11. 1). Metric analysis is very close to angular scale within a walkable radius distance from each street segment. As we increase the radius, we find that the correlation between metric distance and angular distance becomes weaker and weaker. This means and the angular geometry and the metric geometry of urban grid are likely to highlight different features on the global scale. The significant routes rendered by angular analysis were often compatible with movement flows. However, when measuring on metric distance, the analysis proved to be less powerful correlate to pedestrian and vehicular movement (Hillier et. al., 2009). It is important to emphasize that metric analysis of larger urban areas is not useful for the purpose of urban modelling and forecasting. Indices of metric distance might highlight walkable areas on a local radius. Patchworks are normally highlighted by measuring the metric mean depth of the system within a certain metric radius. It is important therefore, to be aware of the kind of local areas one needs to reveal, because by making the radius too small (radius 400 metres for example) the patchworks will pick smaller spots of dense local structures. The larger the metric radius, the wider and larger these spots are. A very large radius is likely to expose larger voids and compact districts in an urbanised area, but bears no relationship with movement and its socioeconomic consequences. If we take the metric mean depth of all elements within the analysed urban system o the X axis and plot it against metric mean depth of radius 1000 -for example- we might be able to highlight a pattern of peaks and troughs that is representative of how far a metrically defined local cluster. It is important to remember that the density of street structures and the performance of different radii are also related to the distribution and size of urban blocks. At the centre of a spatial system, as blocks shrink to a smaller size, street structures intensify and metric mean depth decreases. The exact contrary happens when blocks grow larger in size at the centre of an urban region. It must be recognised that city centres tend to intensify their grid structures in central areas to minimize depth.

Where patchwork maps seem to highlight areas of analogous characteristics in terms of scale and network distance, another model might be used to detect discontinuities in maps (Yang & Hillier, 2007). Yang's model accounts for the change in node count values while changing the radius around each element in an urban system. The spatial network starts picking discontinuities which in turn correspond to patchwork maps. In general, metric depth and node count values play a crucial role in determining the properties of local grid structure. However, as we increase the scale of measurement this effect diminishes. At a very large radius, the global attributes of an urban structure can best be represented by its angular topo-geometric configurations.

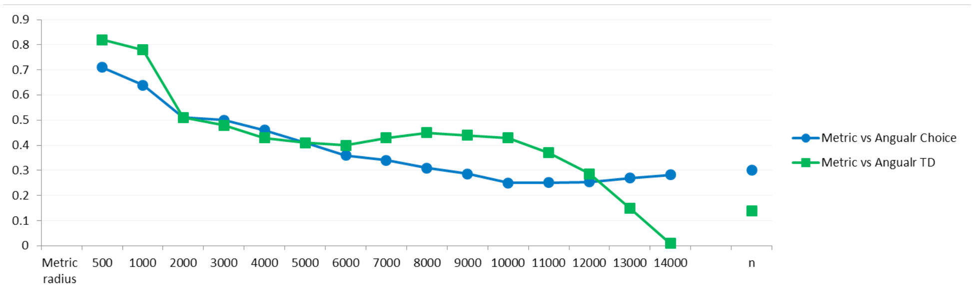


Figure 11.1 . The relationship between metric and angular graph distance in Barcelona. A set of correlation coefficients that mark the relationship between MMD and angular total depth, and between MMD and choice on different metric radii. Adapted from (Al_Sayed, 2013).

Foreground Analysis: Producing topo-geometric analysis

Global structures in cities are often recognised as the set of near-continuous linear connections that afford shorter journeys from all origins to all destinations. It is perhaps reasonable to recognise a global road infrastructure network as a separate foreground layer in an urban grid. As we have seen, metric measures can only function well on a small local radius whereas global radius is mostly topological or topo-geometric. If we start calculating metric mean depth or node count on a small radius from each segment element the resulting values of physical distance will start highlighting local structures (figure 11.2). Once we push the radius higher, an overlapping effect starts to emerge (Hillier et. al., 2009). More overlaps between the 'buffer zones' around each single element arise and this demands a less intuitive measure to calculate the depth and journey cost relationships of the system as a whole.

If we look at the integration measure, the best way to illustrate important linear connections is by calculating angular turns within a metric radius. At radius 'n' the i ments on this measure yield that a simple weighting of integration values by segment length does not make that much difference on the whole. As the system increases in size, the configurational values of street elements follow a lognormal distribution, reducing the difference between mean values. This does not apply to indices of choice, mainly because the values of choice are likely to follow an exponential distribution.

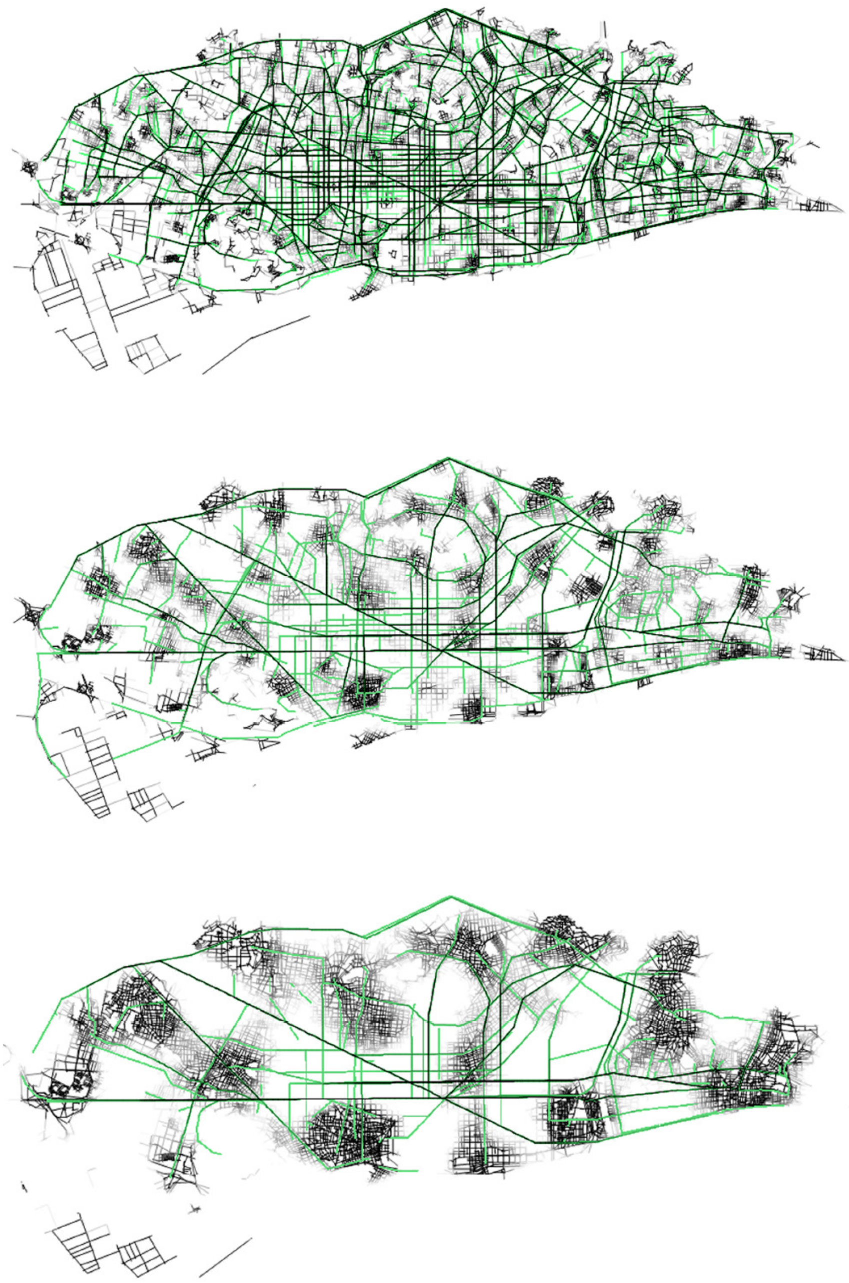


Figure 11.2 . Overlaying the foreground structure on top of the background structure. Smaller radii are applied to both metric and angular measures to render local patterns (top), whilst larger radii are applied to show global patterns (down). The analysis reveals varying patterns of clustering in the background and branching of semi-continuous lines in the foreground Source: Al_Sayed, 2013, LSE.

In a large scale system, choice does not seem to work well when applying metric weighting or angular weighting. In fact, a seemingly trivial effect on a local segment of the route can add up in computing values leaving a negative impact on the representation of the system as a whole. Restricted choice radius, however, performs much better in measuring the network affordances for movement traffic, especially when applying metric weighting. The best method for weighting choice would be to weight the origin and destination of the shortest angular turn journey (Hillier et. al., 2009). In this way, it will allow for the inclusion of the block size variable in weighting origin and destination segments. This solution might be less effective when computing shortest journeys within radius 'n'. Yet, the calculation of least angular turns is more effective than calculating shortest metric distance. Hence, whether calculated separately or combined in one measure, an analysis of angular choice and angular integration are usually reliable in highlighting the foreground layer of street structures.

DEPTHMAP EXERCISE

Advanced Segment and Axial Analysis: Foreground vs. Background analysis

Files available for you to use in the exercise

FILES	DESCRIPTION	SOURCE	COPYRIGHTS
CityLondon_axialmap.MIF CityLondon_axialmap.MIDI CityLondon_unlinks_coord.MIF CityLondon_unlinks_coord.MIDI	MapInfo exchange file containing intersecting series of line elements and MIDI sequence	http://moodle.ucl.ac.uk/	Fewest line map of the city of London data copyright © University College London

Tasks

Import a dxf file into Depthmap with its associated unlinks data

Analyse the axial map

Get from axial analysis to segment analysis[20]

Select angular analysis to render out the foreground structure of the area highlighting the longest semi-continuous lines.

Produce metric analysis to illustrate the background structure of the urban area by highlighting the patchwork of shorter lines.

Steps to perform axial and segment analysis in Depthmap

In this exercise you will learn to do the following activities in Depthmap in order to do Produce Foreground analysis and Background analysis from your axial lines map.

[20] Do not convert your map directly to a segment map! You must make an axial map first to preserve the links/unlinks if there are any embedded in the file.

1. Download your files

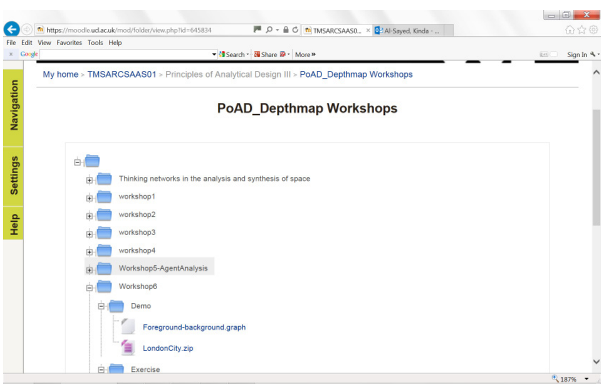
Go to http://moodle.ucl.ac.uk/

and download the zipped file named < london-city.rar> from the website onto your desktop.

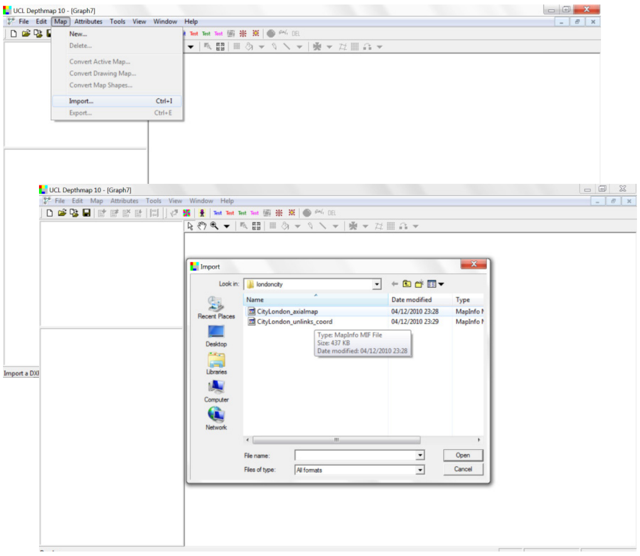
Once you unzip the folder you will find that it contains these four files:

1. CityLondon_axialmap.MIF
2. CityLondon_axialmap.MIDI
3. CityLondon_unlinks_coord.MIF
4. CityLondon_unlinks_coord.MIDI

Copy the files into a new directory on your desktop



2. Prepare your axial map



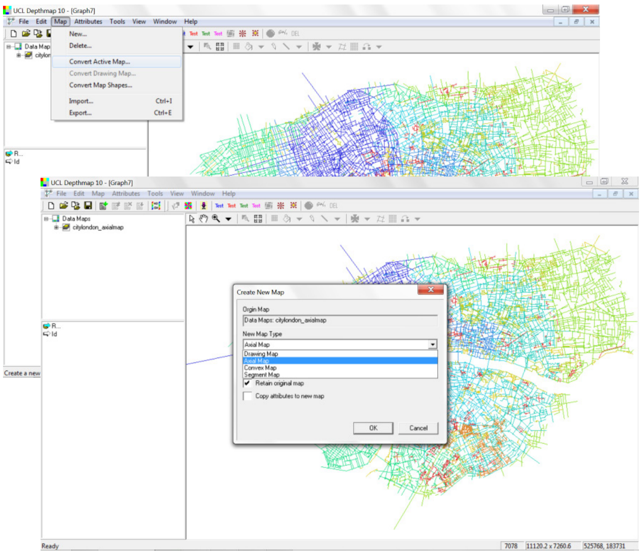
Create a new file: Go to FILE---NEW. This gives a blank page.

Save the file you are using: FILE---SAVE

Choose the name and location of your file

Import the axial map into Depthmap: go to MAP--- IMPORT--- look in your Desktop for a file titled CityLondon_axialmap and Choose the MIF file and click import. Now you will have the file imported into your Depthmap file as a drawing layer. You will be able to see the basic attributes of the file, which are; REFERENCE NUMBER and ID.

3. Axial analysis



Convert your drawing map into an axial map. To do that, go to MAP menu and choose CONVERT ACTIVE MAP.

A pop up window will appear. Under the NEW MAP TYPE choose AXIAL MAP[21].

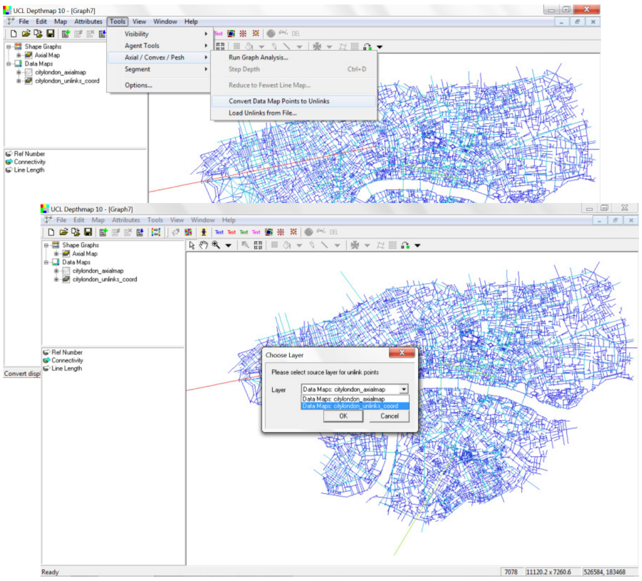
[21] Please note that this step differs to that of importing a DXF file in which you have to convert drawing map instead of active map. From this step on, the procedures undertaken to analyse the map is similar in both DXF-based and MIF-based formats.

You could change the map name under NEW MAP NAME. The default is AXIAL MAP and it will number it if you have more than one axial map.

Once you have done that you will be able to see the basic attributes of an axial map, which are; REFERENCE NUMBER, CONNECTIVITY, LINE LENGTH.

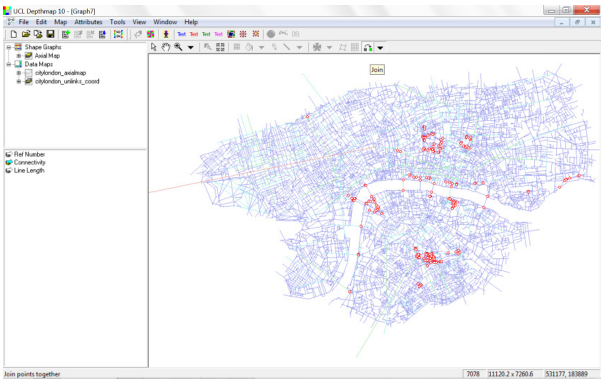
At this point, you may import the unlinks file into your current graph file as a data layer. Go to MAP--- IMPORT--- look in your data folder for a file titled CityLondon_unlinks_coord and choose the MIF file and click import. Now you will have the file imported into your Depthmap file as a data map containing the following columns; REFERENCE NUMBER, X, Y.

Now make sure that you turn off the unlinks data layer. This should activate your previous axial map layer.

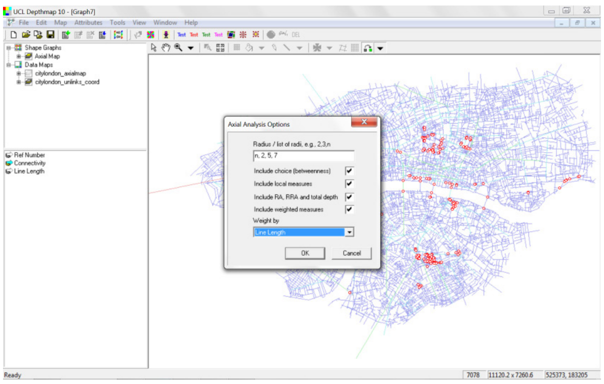


Go to TOOLS---AXIAL / CONVEX / PESH---CONVERT DATA MAP POINTS TO UNLINKS. A window should appear asking you to select source layer for unlinks points.

Select from the browser the name of the data layer containing unlinks data. The unlinks are stored there in the form of points coordinates (X,Y). Click OK.



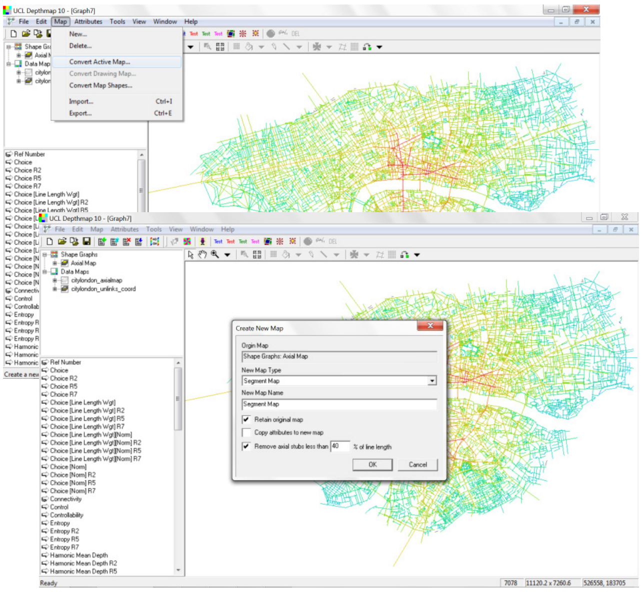
In order for you to check your loaded unlinks data, from the Icons in the toolbar above your map window choose join icon which is displayed as two boxes with a curvy arrow in-between them. You will be able to see all the unlinks data located on your map. Now choose the select icon to view your axial map again.



Make sure your axial map is activated and then go to TOOLS---AXIAL / CONVEX / PESH---RUN GRAPH ANALYSIS. A window will appear in which you could fill in the different radii you wish to analyse (n, 2, 4, 6 for example). Check the three options if you wish to include choice, local measures, RA, RRA and total depth measures.
You could also include weighted measures if you think they might be useful in your case.
You will see so many measures on the left hand of your screen, only few of them will be of interest to you in the future.

Please save your file before you go further.

4. Creating a segment map



Convert your axial map to a segment map. You can do this by going to MAP menu again and choose CONVERT ACTIVE MAP.

A pop up window will appear. Select SEGMENT MAP from the NEW MAP TYPE menu.

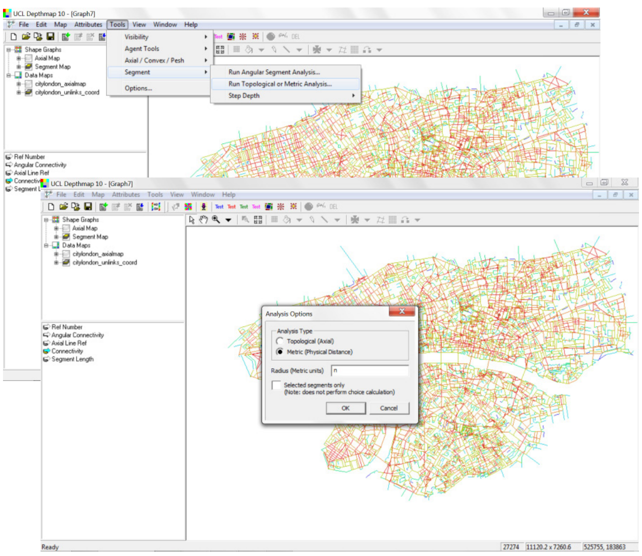
You could change the map name under NEW MAP NAME. The default is SEGMENT MAP and it will number it if you have more than one segment map.

From the ANALYSIS TYPE choose the option to REMOVE AXIAL STUBS LESS THAN 25% OF LINE LENGTH (25% is the default if you choose this option)[22].

[22] You could change this value in a way that suits your map interpretation. This often depends on the length of axial lines you have because you don't want to remove long axial stubs as that might lead to missing important information in the map you have.

At this stage you will only see several columns on the left hand side of the screen; REFERENCE NUMBER, ANGULAR CONNECTIVITY, AXIAL LINE REFERENCE, CONNECTIVITY, SEGMENT LENGTH, note that the segment map will inherit the unlinks data points from the axial map.

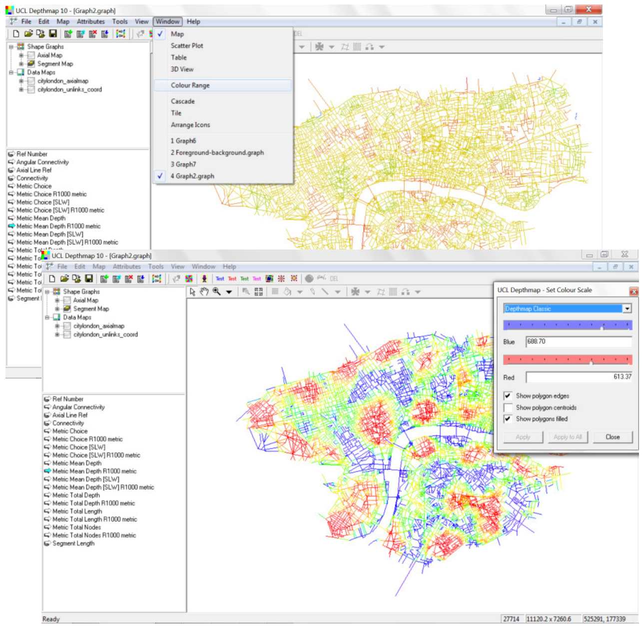
5. Background analysis: Calculating metric mean depth



Go to TOOLS ---SEGMENT--- TOPOLOGICAL AND METRIC ANALYSIS.

A pop up window will appear. Select the type of analysis you want to perform -in this case it is the METRIC analysis- and then insert the metric radius you are interested in such as (1000). Click OK. You will be able to see a list of measures on the left hand side of the screen. The most important measure is the metric mean depth measure. In our case it is the "Metric mean depth R 1000 metric".

At the first instance, when you try to view the effects of metric mean depth on the map, you

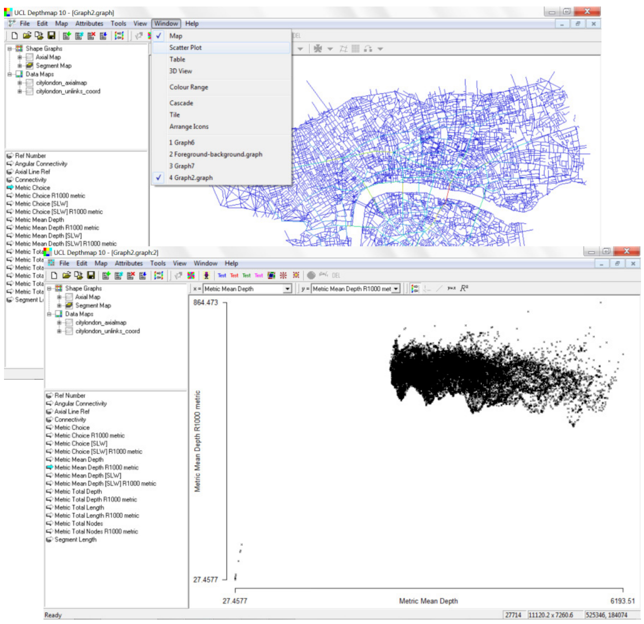


might not distinguish any pattern. To start distinguishing 'patchworks' in the map you will have to adjust the colour range.

Go to WINDOW---COLOUR RANGE. A window will appear.

Use the browser to move to Depthmap classic as a banding range type. Adjust the cursors in such a way as to invert the red-blue range and keep applying the analysis until you get a satisfactory representation of the data values in the form of patchwork map. Note that you are only trying to display the distribution of numbers so you are not changing the numbers themselves.

You could repeat that calculation by applying radius 'n'. Again you could do that again by applying radius 1500 metres.



Once you have done that, you can start looking for patterns and correlations in values. To do that, go to WINDOW---SCATTER PLOT.

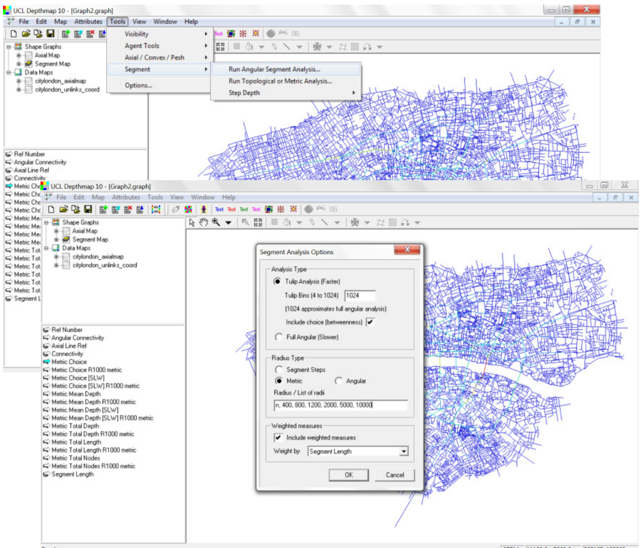
A different window will appear on top of your map window. Change the X axes to represent "metric mean depth" and change the Y axes to represent "metric mean depth R1000 metres". You will be able to see the signature of area-isation of the patchwork map plotted in the form of peaks and troughs. You may also select some of the peaks and check their locations on the map window. The smaller the metric radius you choose the sharper the peaks and troughs will be.

At this stage you may want to check the corre-spondence between the patchwork spots you have and real areas on a real map by opening a windows explorer window and going to Google map. Zoom into London area. See if the areas match existing areas.

Save your file.

6. Foreground analysis[23]: calculating global integration and choice values

[23] Most description of segment analysis is rather technical, but it would make sense to read the papers about it: Hillier and Iida (2005) and Turner (2007). For some historical perspective, you might also like to look at Dalton et al. (2003), although note that Dalton et al.'s fractional analysis differs in detail from the later methods.



Run the segment analysis: by going to TOOLS---SEGMENT---RUN SEGMENT ANALYSIS.

A pop up window will appear showing SEGMENT ANALYSIS OPTIONS.

Choose the default TULIP ANALYSIS rather than FULL ANGULAR. Tulip analysis does everything that full angular does and much more. Also ensure you select INCLUDE CHOICE (BETWEENNESS).

For RADIUS TYPE, change to METRIC, and select a range of suitable radii to measure. Everything at this stage hinges on whether or not you made sure you scaled your map correctly in metres. If you did, then a list of sensible radii to plot global connections might be: n, 3000, 5000, 7000 with a comma but no gap between each (no comma at the end).

Also make sure that you tick the box marked INCLUDE WEIGHTED MEASURES and select weight by SEGMENT LENGTH from the drop-down menu.

Click OK and the analysis will run. A box will tell you how long it will take. If this will take too long try to run the analysis at home and save the file on your remote desktop driver.

Once the analysis is finished you will have a series of measures the most important of which is T1024 CHOICE, a possibly good representation of the foreground layer. Note that this is different from axial choice measure.

Ignore for the time being those measures with 'Norm', and 'Segment Length Weighted' (and

the combination of the two).
Another representation of the foreground layer is identified through global integration measure

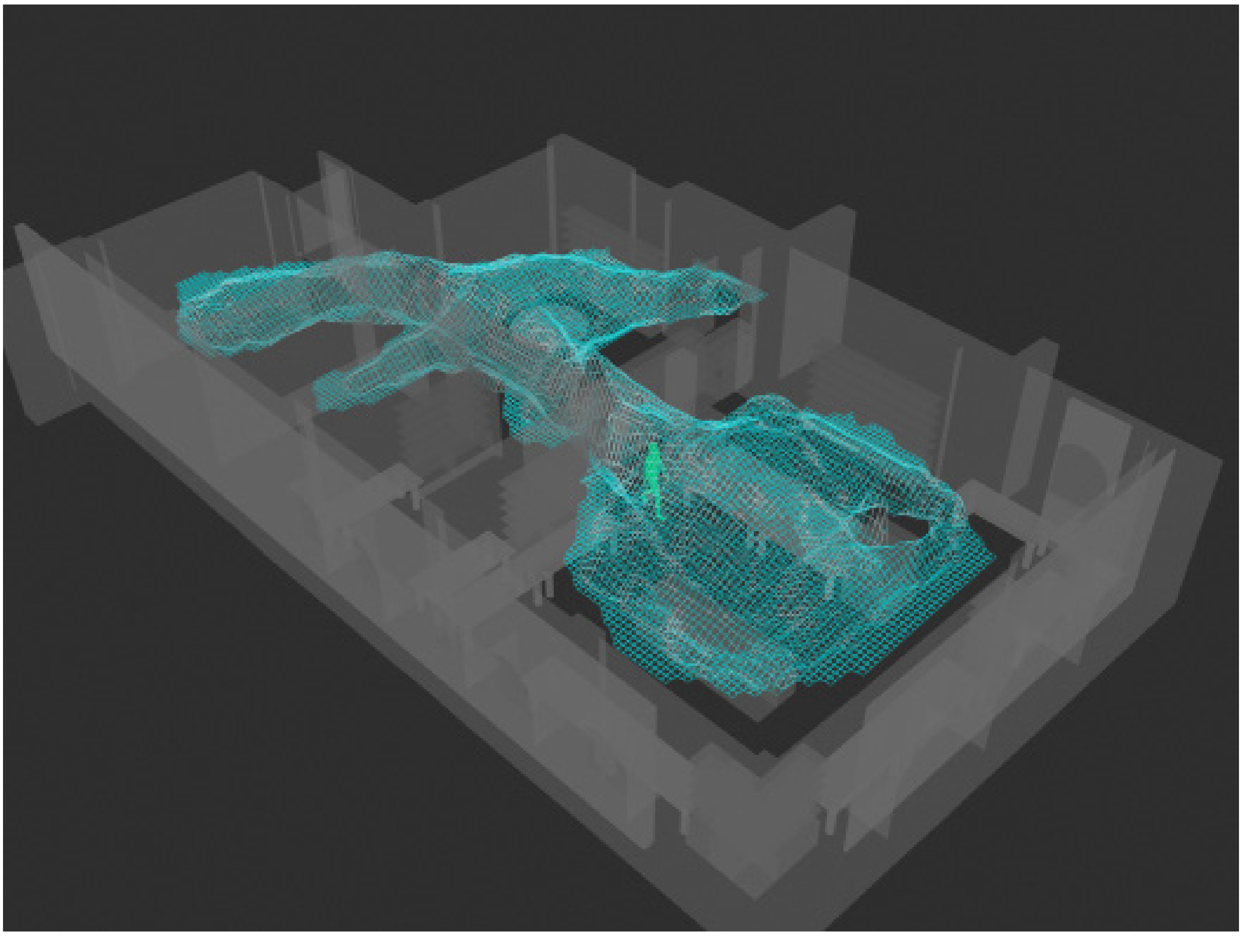
At this stage you may want to check the correspondence between the catchment area of an important road and the lines highlighted by the foreground layer. You can do so by opening windows explorer and checking Google map. Zoom into London area. See if the routes identified by choice Rn for example match highly significant roads in the street network.

Notes

Save your file whenever possible. Depthmap tends to crash sometimes when analysing large graphs.

If you stop your analysis before it is actually finished for whatever reason (often because the analysis is taking too long) the graph will be analysed only partially. So you will have to produce another active layer of analysis. If you don't want to confuse half-finished analysis with the finalized one within one layer you will have to delete the columns of the partial analysis one by one. Note that some columns cannot be deleted.

AGENT ANALYSIS



THEORETICAL BACKGROUND ON THE AGENT MODEL

Introduction

This chapter introduces the cognitive agent-based model and simulation techniques that are incorporated with the Space Syntax tools in UCL Depthmap10.14. The cognitive agents, developed by Alasdair Turner, introduce a dynamic description to the static representation of Space Syntax model in that it accounts for the adaptive behaviour of individuals/agents in relation to space. This section will be dedicated to introduce the theoretical and modelling description of Turner's cognitive agents.

Different Agent tools are provided on the 2D and 3D graph windows to visualize aggregate and individual agent movement. These tools were initially dedicated to form the experimental part of Alasdair Turner's research, for this reason further testing is needed to validate the rules on different building typologies and different architectural and urban scales. The manual explains the use of the Agent Analysis Setup toolbox in the graph window. The toolbox enables users to generate different patterns of aggregate behaviour by controlling the parameters and rules in the toolbox window. In addition, the manual explains some of the tools provided on the 3D view window that control the visualisation of the standard agents. The 3D view helps understanding how individual movement behaviour of standard automata/agents builds into aggregate patterns that might then be compared to human behaviour in space.

The chapter describes the application part of a theoretical framework developed by Alasdair Turner; namely his theory on 'Embodied Space' in which he seeks to explain the natural visual interaction between the individual and the environment. To test his theoretical investigation, Turner devised an Agent's model architecture to simulate natural movement patterns in buildings and cities. His model reflects on several levels of investigation where he initially tests simple automata that act by means of direct visual affordances using simple rules. He then evolves his automata by assuming that his agents or animats can make choices about certain visual characteristics of the environment. The last stage of his investigation is where animats acquire the ability to learn and utilise memory in different environments. This investigation is partly implemented in the Agent analysis tool in Depthmap 10.14. The Agent model is instrumental to acquire a better understanding of the cognitive basis of natural movement and probably explain navigation and wayfinding.

In separate experiments that were implemented in previous EVAs application, Turner et. al. (2004) has also demonstrated possibilities for the Agent model to be devised as a generative design tool to coevolve agents and spaces. The design was an emergent product of users' movement using predefined rules. Turner's agents act upon their visual perception in relation to their position within the environment. As they move through space, the visual information they receive through their visual devices change and their reactions change accordingly. This process involves a dynamic component, and in this way it differs from Space Syntax representation. The Agent model starts from the irreducible elementary actor in the system, that is the individual, and present the visual dynamics that direct his movement aiming to understand and reproduce the process of inhabitation and occupation in space.

The Agent analysis tools in the 2D view window (Map window) are used to generate aggregate models of agents' movement in space. These aggregate models are governed by global parameters as well as parameters defining the behaviour of individual agents. The global parameters determine the duration of analysis, when, where and how many agents are released into the system. They also allow for externalising agents data to compare with movement traces and with observed gate counts. The agents' parameters will define their field of vision and the number of steps at which they decide to change their directions. The agents may follow different rules to see or take turns in the system. These rules are in need of further testing by measuring the correlation between the model and observed movement patterns. Empirical testing would help understanding the basic cognitive mechanisms that drive explorative and planned movement behaviour in relation to space.

The 3D view window provides the advantage of a 3D visualisation of agents in action. The 3D view may cast more light on the individual and situated behaviour of agents; hence help to understand the notion of situated cognition, as suggested by Alan Penn. It helps tracing the decision-making process embodied in agents' movement actions and reactions to spatial affordances. It allows for the observer to track localised movement patterns, thus helping to design a case-sensitive approach to simulate natural movement in a particular system. It must be emphasised here that the 3D view in this version of Depthmap10.14 can only show the standard automata, not the evolved or learning animats.

DEPTHMAP EXERCISE
Agent analysis in Depthmap

In this tutorial we are going to explain how to produce Agent analysis using the different parameters settings in Depthmap. First, create a new file in Depthmap and import a drawing file (either DXF or MIF file). The drawing you are importing should have closed boundaries in order for you to be able to make Visibility Graph before you start the agent tool. After you import the file follow the steps to make a visibility graph, first by setting the grid using the SET GRID button . The default value is 0.04. You could simply adjust this value by entering a different number, preferably to be 0.02 to match human scale. This is up to you and it depends on the resolution of the analysis you need to obtain. After you set the grid, you can fill the enclosed spaces using the FILL button . Click inside the area you want to analyse and it will fill it with a different colour marking the enclosed space in which agents are going to move about. After you have done all this steps to prepare a space for analysis, you have to make a visibility graph out of two attributes the grid and the boundary that you have filled. In order for you to do that, go to

TOOLS---VISIBILITY---MAKE VISIBILITY GRAPH

A window will appear providing you with visibility graph options. Just click OK and it will make visibility graph. Now your settings are ready for Agent Analysis.

Go to TOOLS---AGENT TOOLS ---RUN AGENT ANALYSIS
The following window will appear.

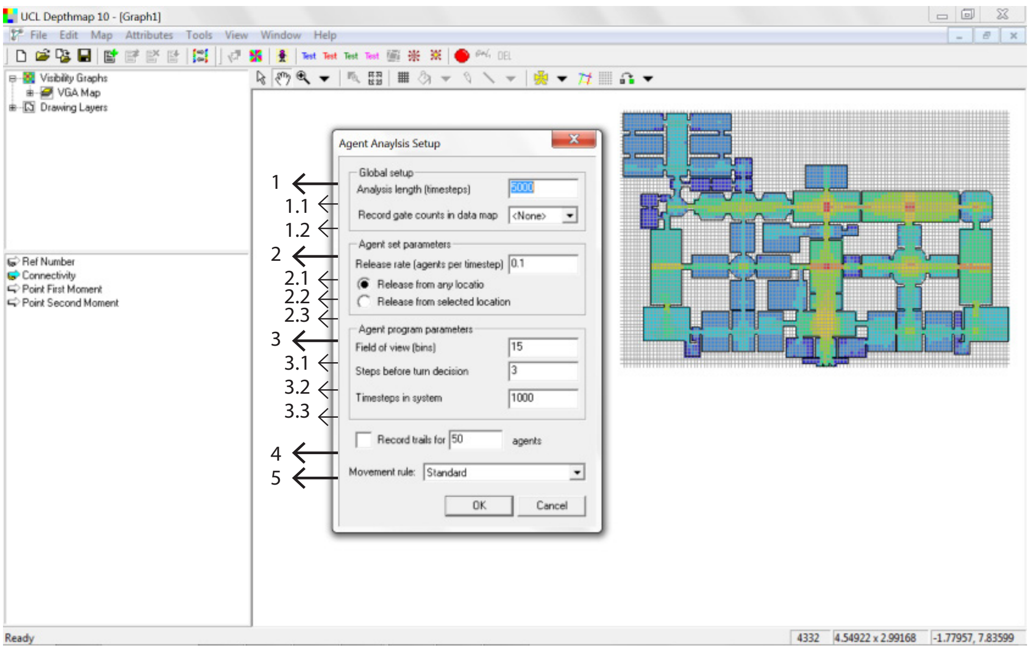


Figure 13.1. Agent analysis setup in Depthmap.

In order to explain the window we have marked the different parameters with numbers and a short explanation will be associated with each number.

7. Global setup

Sets the global attributes of the agent movement in the system

1.1. Analysis length (timesteps): Sets the period of the analysis in timesteps

1.2. Record gate counts in data map: records how many agents are passing through predefined gates in a new column. These gate count values are stored in a data map layer and can be compared to observed gate counts representing pedestrian flow per time unit in the real built environment. Normally you will need to log the values in both data map columns because the values will be exponentially distributed and in order to calculate their correlation coefficient they need to be normally distributed. You can log the value by just adding a log function when updating the two columns.

8. Agent set parameters

Sets the attributes of agents releasing mechanism in the system

2.1. Release rate (agents per timestep): Sets how many agents are released to the system within each time step.

2.2. Release from any location: A check box giving you the option of releasing agents randomly from any location in the predefined space.

2.3. Release from selected locations: A check box giving you the option of releasing agents from previously selected locations. You will have to select the locations from which you want the agents to be released before you start your Agent analysis. Normally you will need that to simulate the flow of people starting from the entry points in the layout such as the main entrance, stair cases or elevators. This technique also helps when the observer needs to compare observed movement traces to traces that agents leave behind when moving from the same point that the observer has followed people from. In order to select locations on your grid you have to press the left mouse button and keep it pressed while you define a window containing the points you need and release it once you are done. If you want to add to your selection you will have to hold the SHIFT button will you define a new selection using your mouse.

9. Agent program parameters

3.1. Field of view (bins): This attribute will define the field of view that each agent can see when moving in certain direction. The default is 15 bins which is equivalent to 170 degrees. It have proven to be most effective when comparing to natural movement patterns. However, it is up to the researcher to change this field of view subject to the particularities of the case under investigation.

3.2. Steps before turn decision: These are steps or grid points that the agent passes through before choosing to randomly change direction in relation to the environment surrounding them at the time it has arrived at the last step. The default is 3 steps and it has proven to correlate best with natural movement patterns. Again, it is up to the researcher to change that.

3.3. Timesteps in system: There are time steps that the agent move about in the system before it disappears. Normally this will be relative to the distance chosen between the grid points and the walking distance that a pedestrian may take in a certain urban or building environment.

10. Record trials for

This option will export the movement traces to a file called trails that will be stored within the folder where you have your original graph file. You can import that file after you have done your agent analysis and Depthmap will store it as a separate drawing layer.

11. Movement rule

There are different rules within this drop down list. It is advised that you use the standard rule which is the default. The rest of these rules are part of an ongoing research and need to be further tested before implementing in natural movement simulations. Further information about these experiments might be followed in Turner (2007a). The occlusion rules are of particular interest. However these rules will not work properly unless you calculate isovist properties. For that you have to go to

TOOLS --- VISIBILITY --- RUN VISIBILITY GRAPH ANALYSIS --- CALCULATE ISOVIST PROPERTIES

Visualising agents movement in 3D view

In this section we will demonstrate how to use the Agent tools in the 3D view window. The first step to do that is to open the 3D View from the Window Menu. The 3D View window like the one you see in Figure 13.2 will appear and you will be able to see on top of the window as highlighted a set of icons that may be used to create, control, visualise and view Agents' movement. The functionality of each single tool is explained below.

Click this icon to enable you to drop a new agent within the scene.

Click this icon to enable agents' movement after you have deliberately stopped it

Click this icon to pause agents' movement

Click this icon to stop agents' movement

Click this icon to enable traces to be drawn tracking agents' movement routes.

Click this icon to enable you to control the orbit zoom of the 3D view.

Click this icon to enable you to pan your view in different directions.

Click this icon to enable you to zoom in your view

Click this icon to enable you to have a continuous zoom

Click this icon to enable you to see the gate count values and how they emerge and change as the agents move on the grid.

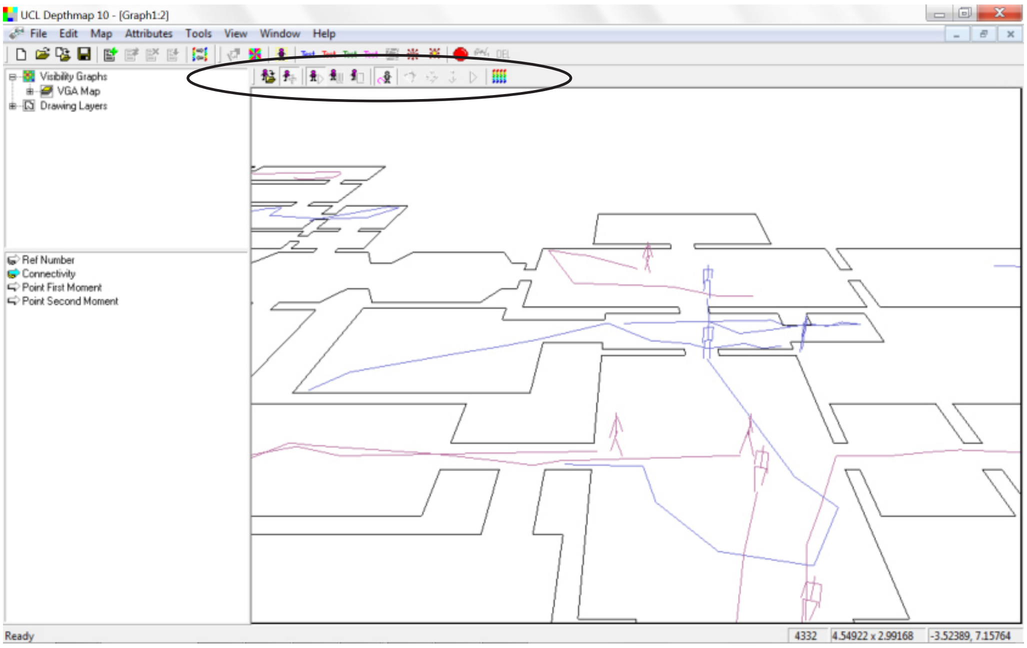


Figure 13.2. Agent tools that may be used to demonstrate realtime behaviour of individual agents in a 3D view window in Depthmap.

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https://github.com/SpaceGroupUCL/Depthmap

UCL Depthmap website
https://www.bartlett.ucl.ac.uk/graduate/research/space/research/ucl-depthmap

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APPENDIX 1

Topological Measures of Space Syntax

The simplest graph measure of Space Syntax; that is Connectivity $C_i = K_i$, defines the configurations of local structures in street networks; where C_i –in axial analysis- is the number of axial lines connected to the i-th axial line. Beyond graph Connectivity, there is a set of global static and dynamic measures of the graph configurations that are thought to be more predictive and postdective of pedestrian and vehicular movement (Hillier et al, 2012), and perhaps the economic consequences of this movement (Hillier, 1996a).

The global measures are derived from the graph topological depth, which accounts for the distance between each axial line and all the others, where the shallowest axial line is the closest to all other axial lines and the deepest is the furthest one. Depth is a topological distance between vertices in the dual graph G. Two open spaces, i and j, are said to be at depth d_{ij} if the least number of syntactic steps needed to reach one vertix from the other is d_{ij}. The sum of all depths from a given origin is computed as Total Depth;

$$TD_i = \sum_{j=1}^{n-1} d_{ij}\,, \qquad i \neq j$$

The Mean Depth of the graph representing average distance of the i-th axial line from all the other n – 1 in the dual graph G is computed as follows;

$$MD_i = \frac{1}{n-1}\sum_{j=1}^{n-1} d_{ij}\,, \qquad i \neq j$$

Depth might be calculated for the whole graph G containing n vertices, or for a certain number of neighbouring vertices within a predefined graph distance from each vertex. For example, Mean Depth at radius 2 might be defined as the average distance of the i-th axial lines from the other w-1 axial lines at a distance $d_{ij} \leq 2$;

$$R2\,MD_i = \frac{1}{w-1}\sum_{j=1}^{w-1} d_{ij}\,, \qquad i \neq j$$

Using the topological measure of depth, it is possible to deduce the structural properties of the system by deducing the Relative Asymmetry RA! values. RA represents the centrality of an axial line comparing its actual Mean Depth with the theoretical highest and lowest values that Mean Depth could have in the given graph. Compared to Mean Depth alone, Relativized Asymmetry is a normalization of depth to fit values within the range [0 , 1]. RA! is the normalised value of being min (MD!) =1 and max(MD!) = n/2;

$$RA_i = \frac{2(MD_i - 1)}{\mathrm{n} - 2}$$

The problem arises with RA is that the limits that depth is being scaled to are quite extreme. To enable a comparison between systems of different sizes and between local and global structures within the same graph, a normalisation of the graph measures is needed. For this purpose, a dedicated 'Diamond' D-Value was computed to normalise graphs that are representative of architectural or urban spaces (Kruger, 1989). Normalization using the D-Value is obtained through comparing a centrality measure of the i-th vertix of a graph with n vertices with the centrality measure we would get if the vertix was at the root of a graph of the same number of n vertices but is justified in a diamond shape (Kruger, 1989; Teklenburg et al. 1993; Hillier & Hanson, 1984). In such a graph, depth values are thought to follow a normal distribution; therefore, comparing the RA value of its root to that of a vertix in a graph with the same number of vertices is a way to compare a normal distribution with the actual distribution. In this type of graphs the D-Value (Hillier & Hanson, 1984) is computed as:

$$D_n = \frac{2\{\mathrm{n}\left[log_2\left(\frac{n+2}{3}\right) - 1\right] + 1\}}{(\mathrm{n}-1)(\mathrm{n}-2)}$$

In order to make the centrality measure of RA independent from the size of the graph, Real Relative Asymmetry (RRA) values were computed to allow for a comparison between graphs of different sizes. RRA is derived by normalising RA values by the D-Value;

$$RRA_i = \frac{RA_i}{D_i}$$

Using the aforementioned measures of street networks, Space Syntax has developed two major indices of Centrality that capture the relative structural importance of a street represented by a vertex in a dual graph. The Centrality Closeness, defined as Integration in Space Syntax terms, is expressed by a value that indicates the degree to which a vertix is integrated or segregated from the urban system as a whole (global Integration), or from a partial system consisting of vertices that reside within a neighbourhood that is defined within a certain number of steps away from each vertix (local Integration). The global measure of Integration is computed as follows;

$$INT_i = \frac{1}{RRA_i} = \frac{D_i}{RA_i}$$

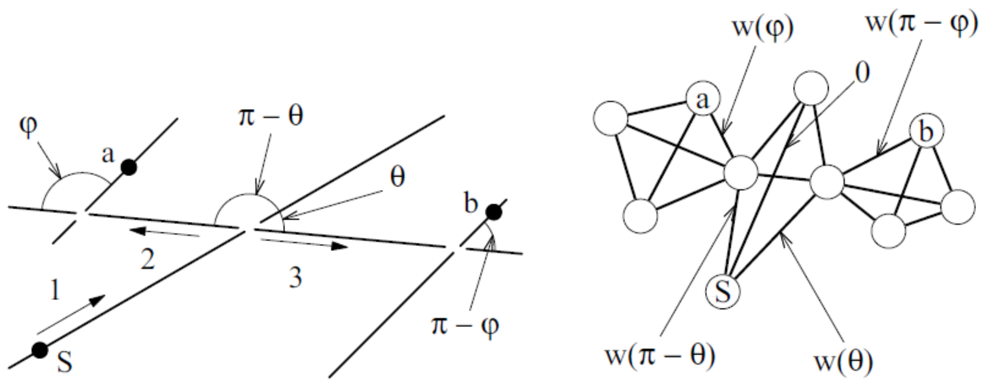
Another graph measure is Betweenness Centrality; redefined as Choice in syntactic terms; that is the number of the intermediate vertices that stand on the shortest path between i and j. Choice is a dynamic global measure of the flow through a space $i \in G$. It captures how often a vertex –an axial line- may be used in journeys from all origins to all destinations in a street network. Vertices that occur on many shortest paths between other vertices have higher Choice values than those that do not. Global Choice can be computed as the ratio between the number of shortest paths through vertix i and the total number of all shortest paths in a graph G. To go back to the mathematical definitions, centrality 'betweenness' was defined early in network theory as "the weighted frequency a point falls in the shortest path between all origins and destinations in a given system" (Freeman, 1977). A calculation of Choice within different radii can render out the shortest path routes on different local and global scales. Unlike Integration which is normally or lognormally distributed, Choice values are distributed exponentially. Most axial lines render very low values of Choice, whilst a minority of axial lines reserve higher values than the average and constitute the foreground of the urban fabric. Choice is computed as follows;

$$Ch_i = \frac{\sigma_{s,t}(i)}{\sigma_{s,t}}$$

APPENDIX 2

Angular Analysis of Street Networks

This section explains the angular weighting concept as implemented in Space Syntax to measure graph distance in street networks. The concept was originally introduced in (Hillier & Iida, 2005) and was later applied in UCL Depthmap (Turner, 2011). To measure angular graph distance, the original axial map introduced in (Hillier & Hanson, 1984) was again broken up into a segment map, were segments are defined as the street lines between intersections (Figure 15.1. a). A graph representation of the segment network is shown in (15.1.b), where each street segment is represented as a vertix in a graph G' and each intersection between two street lines is considered to be a link.



a) A segment map

b) A graph representation of a)

Figure 15.1 . A segment map model and its graph representation to elucidate how an angular graph distance is calculated for a street network.

The distance cost between two line segments is measured by taking a "shortest path" from one to the other, so the cost of travelling from a street segment s to a street segment a can be notated as $\omega(\pi - \theta) + \omega(\emptyset)$, while the cost between s and b can be defined as $\omega(\theta) + \omega(\pi - \emptyset)$. The Least angular change (geometric) distance cost is measured as "the sum of angular changes that are made on a route, by assigning a weight to each intersection proportional to the angle of incidence of two line segments at the intersection" (Hillier & Iida, 2005). The weight is defined so that the distance gain will be 1 when the turn is a right angle or 90°, 2 if the angular turn was 180°, and 0 would be the value of angular distance gain if two segments are continuing straight – this is the case when segments belong to one axial line. This description notated as follows;

$$\omega(\theta) \propto \theta \ (0 \leq \theta < \pi), \qquad \omega(0) = 0, \qquad \omega\left(\frac{\pi}{2}\right) = 1$$

This angular cost can then be applied as a weighting function to the Centrality measures of 'Closeness' and 'Betweenness', originally known in graph theory. Closeness or Integration AIN_θ in Syntactic terms is defined as:

$$AIN_\theta \ (x) = \left(\sum_{i=1} d_\theta \ (x,i)\right)^{-1}$$

where dθ is the length of a geodesic (shortest path) between vertix x and i. Angular Betweenness or Angular Choice value for a segment x in a graph of n segments is calculated as follows:

$$ACH_B(x) = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \sigma(i, x, j)}{(n-1)(n-2)} \quad (i \neq x \neq j)$$

where (i, x, j) = 1 if the shortest path from i to j passes through x and 0 otherwise.

Normalising angular analysis of street networks

In order to enable cross scale comparisons between different parts of a city or between different cities, Hillier et. al. (2012) suggested a normalisation procedure for angular weighted graph distance considering a relationship between the tendency of an urban system to optimise travel distance from all origins to all destinations and the cost of segregation that is an effect of the system size. Normalised angular Integration NAINθ for a graph G' with the size n is defined in Hillier et. al. as follows;

$$NAIN_\theta\ (x) = \frac{(n+2)^{1.2}}{(\sum_{i=1} d_\theta\ (x, i))}$$

where dθ is the length of a geodesic (shortest path) between vertix x and i. Normalised Angular Choice $NACH_B$ is defined as follows;

$$NACH_B(x) = \frac{\log(\sum_{i=1}^{n} \sum_{j=1}^{n} \sigma(i, x, j) + 1)}{\log(\sum_{i=1} d_\theta\ (x, i) + 3)} \quad (i \neq x \neq j)$$

where (i, x, j) = 1if the shortest path from i to j passes through x and 0 otherwise.