Fractional Configurational Analysis
And a solution to the Manhattan problem

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Abstract
Configurational analysis has been a very robust and successful tool to the understanding how space and occupation interact. There has been little work to date that tries to refine the core procedure of configuration to see if it is possible to improve on current correlations or remedy problems. This paper attempts to show that such an exploration is potentially rewarding by identifying a new method of fractional configurational analysis. One variant of this fractional configuration is explored which takes angle into account. This new fractional configuration appears to result it a reduction of the centralising effects common to large infinite radius axial-line maps. Future extensions of this work are then discussed.

Introduction

At the heart of the body of knowledge called Space Syntax lies a computation known as 'configurational analysis' [Hillier 1][Hillier and Hanson 1] . Configurational analysis begins by defining a method with which to identify spaces such as an axial line, convex space, overlapping convex space, room or a 'rectangular grid element'. These spaces are observed to have a continuous network of interconnections. Typically a space is said to have a relationship to another space if both spaces intersect. This relationship is seen to be a Boolean one, there is either a connection or there is not a connection between spaces. This mapping of Boolean relationships between spaces can be then treated to form a pure network or 'graph' in the mathematical sense. This network consists of space being a node in the graph with links between nodes being indicators of intersections between spaces. Once held as a graph a number of topological operations can be applied, one of these is to layout the graph from a node (space) to form a J-Graph. The important observation is that with a J-graph it is possible to form numerical approximations to the shape of the graph. The most popular one being to find the average distance from the starting node to every other node in the graph (or system). Even connectivity is an attempt to measure the shape of the base of the J-Graph by counting the number of items directly connected.

The key discovery in Space Syntax is that the notion of average distance from the starting point is different from every starting point. Each node (space) in the graph then has a different (but not necessarily unique) set of numbers which relate to the node. It has been shown in the case of an Axial line representation in an urban situation that the value average depth can strongly correlate with observed movement[Hillier 2].

The computations necessary to calculate the characteristic numbers of a graph by its nature is slow,meticulous and repetitive. Firstly the graph has to be identified, then all the J-graphs for each node in the graph have to be computed. Generally for each description of space there is an associated computer program associated with it, AxialLines with 'Axman', Overlapping Convex spaces with 'Spacebox', convex-spaces with 'Pesh', networks of pure spaces with 'NetBox' and 'NewWave', Isovist elements with 'Depthmap' [Turner2].

Is there anything beyond Axial Line - Integration ?

Looking at configurational analysis with axial lines, there is no doubt that it has been both a very successful, and a generally robust measure - working in both European, Asian, Islamic and American Cities. Over the years, of using configurational analysis a number of problems have become apparent. These have typically been dealt with by improvements to the skill and art of digitisation. This paper proposes the thesis that some of these problems are in fact symptoms that the axial line, integration representation are only approximations -sign posts to another form of processing.

Axial lines

Axial lines are the fewest, longest lines of site which completely describe the spatial structure in question [Hillier and Hanson]. This is one of the most popular ways of describing the urban space prior to the construction of the intersection graph. Others such as Turner [Turner 1] have proposed new methods of spatial representation, so it might be best to begin by reviewing if this nessasry to abandon Axial lines when looking at new forms of processing.

The Black art of axial map construction

While the skill of building a digital spatial representation, speed of processing and art of interpretation and correlation with real movement have all been aspects of great study and achivements, configurational analysis has not changed much from its inception. There appears to be an unspoken assumption that all futher work in space syntax is refining the 'art' of Axial Map construction to handle the ugly cases that arise. All problems are, with this thesis, the result of poor skill on the part of the digitiser.

As an example take the New York/Manhattan map [Stoner] see fig 1 when this is analysed with a geometrically accurate integration map (ones where the axial lines follow the rule of the fewest longest lines of site which completely map a system), the result is that Broadway comes out as a poor integrator. It is known that Broadway is one of the most active lines of movement In New York. To make Broadway become more integrated it is necessary to 'straighten' Broadway away from a geometrically accurate representation. This straightening is a common technque when handleing motorways and flyovers and has been used in a number of axial maps in the urban database.This would seem to doom any possiblity of purely automatic axialine extration from GIS data.

There are a number of rules of thumb in the construction of axial maps, look for natural boundires to the area in question such as rivers and train lines. When a road is difficult to cross then build axial lines for the pedestrian area either side of themaps, join open spaces such as parks via there exits. As such construct motorways as artifical straight is one such rule. This kind of skill raises a questions of reproducibility of methodology of spatial mapping, especially in archeological uses of space syntax. The long term objective must be to give a spacial map to two people and have them produce roughly the same axial map and intergratin values. The more skill and rules of thumb required the less likely it is that two axial maps will match.

One solution to this reproducablity problem might be to change spatial representation completely such as done by Turner [Turner 2]. Or find some way of producing axail maps automtically from descriptions of space such as currently available with software such as space box. and infinity within.

The proposal of this paper is that current spatial representations are viable , so the focus of attention settles on how the configuration is computed. Perhaps the solution is to stick more closely to the spacial accuracy of an axial maps, deskill the axial line construction(ultimately makeing it automatic), but change the processing methods. I will go enumerate some of the problems found when digitising an axial map. Rather than seeing them as perfect representaion and computation and problematic digitisation I want to explore there interpretation as imprefect representation/computation fixed by skillful digitisation.

Long lines of site

Manhattan is an example of how the rules of axial construction (finding the longest line of site which completely represent a space) lead to conflict between our notions of what is and is not a space. Can an axial line really be 20 miles long ? For example is Oxford street in London a 'space'? You can never see completely down its length at any point, alternatively there is no point at which the space clearly dislocates into two or more separate spaces. This is what I term the ultra long line of site problem. Current forms of processing would penalise the use of many overlapping axial lines pushing a multi lined Oxford Street into a series of clearly unrepresentative disjointed spaces.

With ultra long axial lines then we have further problems, for example integration produces one number per space. This number then generally correlates well with observed pedestrian movement in that space. With axial lines 20 miles long we have a problem of either aggregating large variations of values into one practically meaning less value or applying one integration value to a line with a great deal of movement variation. How do you talk about the average pedestrian movement down a 20 mile long axial line ?

Can we then produce a form of processing which would permit the use of more axial lines which would seemlessly blend into one space. These sublines should not add more weight to the map, yet could work together like the ultralong lines.

Curved routes

Curved space such as London crescents, or circular walls again present the constructor of an axial map with a similar problems. If digitising an axial map of a traffic system including a motorway then should one stick to the true geometric use of space or use a few simple bold axial lines which seem to better to represent the simplicity of travelling on a motorway ? Such as found in the AxialMap of Amsterdam

This could be seen as a reinterpretation of the long line of site problem, is it possible to split a single entry into many sub spaces or to reflect mental nature of the object.

Observational convenience

Small numbers of large spaces such as generated with Axial Maps also have advantages when comparing observations to configuration. If the item of observation is very small and there are a great number of them, then assigning an observation to to that space is complicated and requires far more observations to produce a statistically valid picture. The small number of lines generated by axial maps still facilitate such observational techniques such as gate counts.

Logically it seems for the moment that the axial line is still a efficient and reliable representation of space.

Computational Time

The integration measure (described in detail later) is itself at best n squared log n computation. This means that the number of calculations goes up with the square of the size of the system. For example if it took 10 seconds to compute a system of 100 axial lines it would take 46 seconds to compute a system of 200 axial lines and 208 seconds to compute 400 lines and 15mins to compute a system of 800 lines.

Integration computations are then very sensitive to the size of the system computed. In practice most practical programs (such as Axman) are closer to N cubed which would mean the same system of 800 lines taking 85 hours to compute. Other algorithms, such as Choice, are even more computationaly intensive.

This number sensitivity then demands that for an urban level computation the representation of space be very large, reducing the number of items to be calculated to a minimum. New methods at automatic identification of space, with convex spaces - such as computed in SpaceBox, or even all line axial maps (Infinity within) or Isovists (OmniVista , Depthmap) tend to generate large numbers of items to be processed. While being interesting for looking at smaller scale movement, this tends to mean the processing of metrically small systems. This might seem at odds with the notion of configurational analysis, where the large scale and not directly perceivable network of spaces of the city has an effect on the local movement potential.

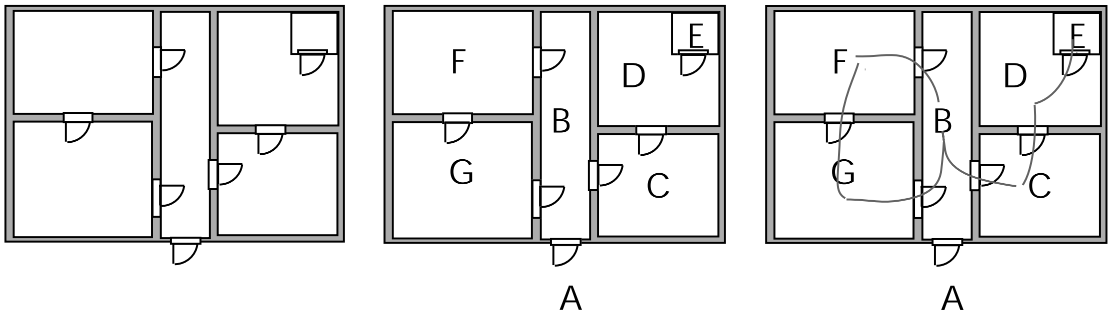
Finally what I term the computational problem hints that for the moment processing and so understanding a city syntatically, requires small numbers of large spatial descriptors. Axial lines suit this kind of processing well. This is not to say that other representations might not be suitable for small areas and buildings, it is to say that urban scale areas need axial line like space descriptions. The computational problem also hints that an algorithm which is not much more complex than traditional intergration measures is required.

Integration or configurational computation

As a prelude to describing a possible solution to this problem, we are now going to look at how normal configrational measures are computed.

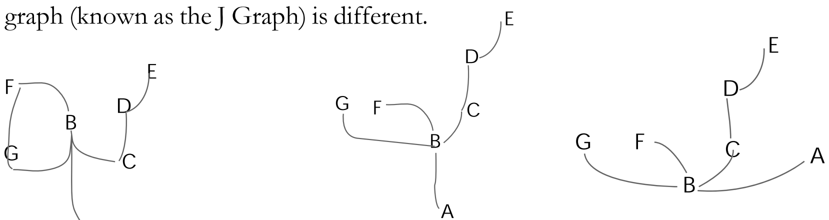
An Introduction to J Graph computation

At the heart of the computation of configuration and one of its measures, integration, is the application of the processing of the J graph. It is best to begin with a quick outline description of how normal configuration is computed. Let us begin with a simple building, a number of rooms are linked with a number of doorways. Figure 1(left) is a simple logical layout. Rooms either connect or do not connect to others.

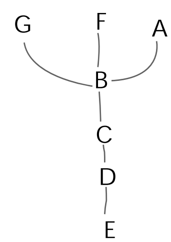


For clarity, we can label each room, and we typically include the outside as the first space. We can then remove the metric qualities of the building, reducing the building down to its topological TcoreY. In this case, we draw a line from each label where a direct pathway links a room to a room (middle). Removing the rooms, we are left with the topological skeleton of the space (right).

The essential discovery of configuration is that when we take this network (or more mathematically graph) representation and lay it out from different view points the shape of the graph (known as the J Graph) is different.



The J graph from A The J Graph from B



The J graph from E

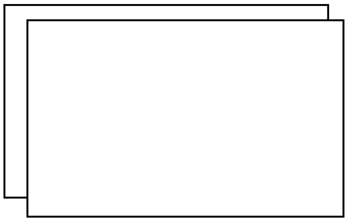
Examining this J graphs the same system looks different. Traditional configuration analysis tries to describe this shape by counting steps of depth. So from E, D is at depth 1, C at depth 2, B is at depth 3, A, G,F is of depth 4(each). This is a total of 18 a mean depth of 18Φ7 = 2.57

From B, A,G,F and C are at depth 1 , D at depth 2, and E a depth 3. This is a total of 8. a Mean depth of 8Φ7 = 1.142

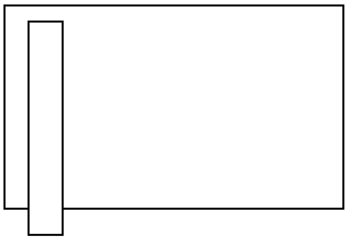
Futher procssing is nessasry to covert mean depth to RA and RRA thence to Intergration (see Hiller and Hanson).

Over Centralisation

When looking at urban systems it is also necessary to realise that current step based configuration tends to focus integration to the centre of the network. This is a very large benefit to the configurational analysis, movement does tend to be in the network centre of the city, however infinite radius integration tends to over prioritise movement to the centre. Note the configurational center need not be near the geometric or historical or finacial center of a city, in the case of Greater London the CBD (central bussness district) and historical center is the city of London ,not the most intergrated line of Oxford Street. An axial line near another axial line will pick up a lot of integration by being connected to a primary integrator. This can be seen in figure 11 where integration is over attributed to roads leading from Pentonville Rd (marked). This problem I call the centralisation problem. This is typically reduced by applying a radius 'clipping' to the total depth map.

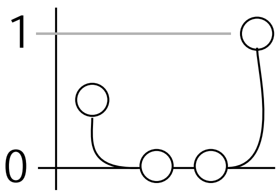


Case A large overlap.

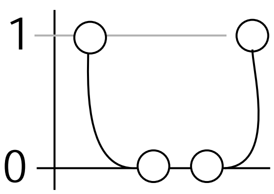


Case B narrow overlap.

26.6



Fractional J graph for Case A and B



Traditional configuration for CaseA and B

Fractional depth computation

The important observation here is that each line is at a rational counting number(1,2,3,4), what might it be if something had a depth of 0.5 or 0.1 or 0.8 ? For a system of rooms, this would not make sense- a doorway exists or does not exist. However, for the case of a convex overlapping space have interesting properties.

Consider two overlapping convex spaces pictured at left. With normal configurational analysis, we are expected to think that two shapes that overlap extensively are identical in terms of the J graph analysis as two shapes that hardly overlap.

If you are in the first case A moving from one space to another is trivial. If you can in case B moving from a corridor like space to an open area is more likely than moving from a open area to the corridor space. In the J graph analysis, we are expected that both cases are identical. This is an inherent limitation of the abstractive phase of moving from spatial to topological representation. Perhaps we could state the fraction as the ratio of the area of non overlapping space to the area of overlapping space. In case A this would give a small number, in the case of complete overlap (identical spaces) this would give a value of zero - .ie an object is at zero distance from itself. In Case B the number would be quite large - near 1 or more approaching the case where the convex spaces do not overlap when the value would be infinitely far apart. Automatic generation of convex spaces via a program like spacebox would construct a space from the door frame. This was originally seen as a fault in the interpretation of space by spacebox. We can now see that such a space would be useful in linking the spaces but not skew the computation via the use of fractions.

Considering the J graph at left, this is the core of the fractional computation. The J - Graph is laid out to form a fractional J graph (F-Graph) where step distances are no longer 1 and so depths from the starting node are not integer counting numbers. For the purposes of mean depth the calculations are the same - we find the total depth of all the nodes and divide by the number of nodes.

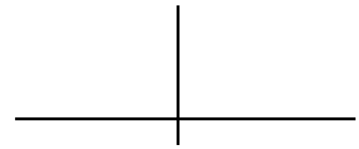
Fractional Axial computation

The mainstay of urban level configurational analysis is the axial line. So the next question is, is there some way of introducing a fraction factor into the intersection of axial lines? One prevalent suggestion has been the introduction of distance into a J graph. This is more complicated than it might at first appear. Consider how a line A might intersect line B, two lines meet at by definition a point, how do we define a length between them? To permit the computation of length does not fit into the simple extension of the J graph we have so far proposed.

The rise of angularity

Recent theoretical [Hillier] [Turner], and empirical work [Conroy] suggests that individuals conserve angle when walking. This implies that shallow changes in the direction of movement should be considered as minor shifts from one space to another.Significant changes in direction could by comparison be seen as deliberate acts in navigation.This could be assimilated in to the fractional J-Graph as shallow changes in angle between two axial lines having low changes in depth (near 0) with sharp changes in angle as being large changes (near 1). Routes having many changes in direction would then be 'further' in the J graph then simple ones.

Shallow angle of incidence (distance near 0.1)



Sharp angle of incidence (distance = 1)

Let us begin by considering the angle of incidence between 2 overlapping lines. Imagine walking down a slowly meandering high street. To model this geometrically we would be forced to model many axial lines which a low angle of incidence between them. Walking along these streets transferring from one line to the next would not be a 'strong' (deliberate) decision. While walking along the same high street, making a change in 90 degrees up a side street would be a stronger decision. We have this in everyday cases, we describe routes as "follow the road then take the next right". Shallow angles then could have low factors for small angles and a large factor for sharp changes of angle (right).

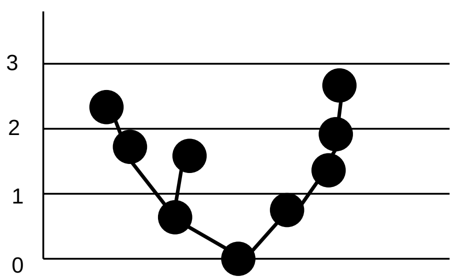
Fractional Angular Analysis works by defining a fractional analysis where the angle of incidence is 1.0 where the axial lines are at right (90 degree) angles. Lines that are parallel and intersect have fractional distance of 0.0. Table 1 shows a comparison of angle to FGraph distance.

Angular Degrees	Fraction
0	0
10	0.17
20	0.34
30	0.5
40	0.64
50	0.77
60	0.87
70	0.94
90	1
90	1

Table 1: angle of incidence against fraction

From this, lines that are nearly parallel have low fractional distances. We would expect this kind of analysis to make long meandering streets of many axial lines become stronger integrators. Equally making one right-angled turn might well mean a strong increase in 'distance'. Intuitively Oxford Street is longer than a single axial line (we cannot see all the way down Oxford Street). With angle of incidence it is possible to use many lines to build one ultra-long line, and to this without increasing 'depth' along Oxford Street. Fractional J graphs then seem to attack the observation and long line of sight problem.

We now can build a network as in the traditional manner, except here the J Graph will have steps which are not 'rational' numbers (1,2,3I) but irrational (or fractional numbers) Such a fractional F Graph will look something like this.



It is still possible to do all the usual processing - we can find the average distance from the starting point. We can also have concepts like 'connectivity angle - co angle' this is similar to connectivity, it measures the total of all the angles of incidence from this line. Given we can build up an average depth we end up with a configurational like measure which in this case is sensitive to angle.

This process has been implemented by a program called Meanda (Mean Depth Angular), This is freely available for academic research from the authors and will be available from the Architectural Association website [AA 1].

Going beyond 90 degrees

It migth be argued that fractional analysis might go beyond 90 degree turns. Take the case of a Y shaped junction. Entering in from the top of the Y going down the page wouldbe a small change of angle, yet going from the top of one part of the Y to the top of the other part of the Y requires a change of angle more than 90 degrees. Yet Meanda would consider

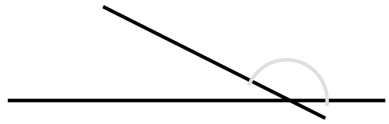


Figure 9

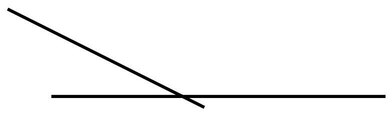


Figure 10

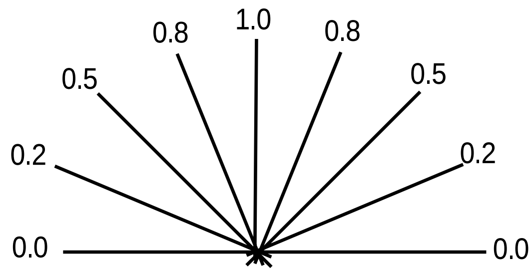


Figure 11

the lesser of the angles. It might be thougt interesting to go beyond MeandaΥs fractional analysis, and try to include a 180 as 1 and 90 as 0.5 and 0 as 0.0. However, consider figure 9. An angle of 140 degrees Meanda would consider this as an angle of 40 (180 - 140).

The intuitive view is that to include a backward angle line, this must improve fractional analysis. After all going back on, your self is a very unusual process in pedestrian movement. However, by rearranging the lines we would find something-different (figure 10)

By moving the line backward, we now sense the line, as being shallow again. To remove this problem Meanda keeps lines between zero and 90 degrees. As shown in figure 11.

Future versions may have the ability to compute this TasymmetricΥ incidence angle. This would require Meanda to consider the concept of origin and some kind of notional TjourneyΥ down an axial line. Currently it would be difficult to adapt Meanda to have the concept of memory and route, the primary intention was to make a direct comparionson between Meanda and traditional configuration computations such as performed by Axman. Once a notion of memory and route is included in a Meanda like program it would then also be possible and for research purposes nessary to include the popular anylitic measures request of metric distance. The only syntatic program which performed origin/destination computations is James Choice, an program which would compute Choice calcuations. This program had a computation limit of n cubed log n which gave rise to the slow computaion reputation of choice, modern computers now give some hope to run such computations on large scale urban systems.This also goes against, in some ways, the notion of configurtational analysis, which is about measureing the urban object. Instead this considers configurational analyis as a simple aggrigation of simulated journey trips, which implies the study of human naviagation is the key factor with the urban configuration as a by product. While asymmetric incidence angle does seem like a nessary step it also seems to be pushing space syntax towards way finding.

Examining the results

To test Meanda and fractional angular configuration it was decided to process the familiar axial map surrounding Barnsbury and New York/Manhattan

In these figures New York is coloured though the colour spectrum from low Mean Depth (blue) to high Mean Depth (red). The values in both cases are the natural logarithm of the values in question, this tends to help identify the top performing axial lines. In this case Broadway has been modelled in a geometrically correct way1 . It can be seen in this normal mean depth calculation that Broadway suffers by being a number of relatively short axial lines which are integrating against a number of much longer and more highly connected axial lines. By looking at the fractional axial map of New York it can be seen that the most integrated route is the set of axial lines which form Broadway. This would then seem to confirm the initial thesis that by altering the manner of processing then problem areas in axial maps construction can be eliminated. Traditional space syntax processing as exemplified in the original thesis [Stoner 1] , would replace the geometrically correct lines with a single axial line to represent the TconceptualY model of Broadway.

Figure 11 shows the area around Barnsbury (an area of London) processed in Meanda using fractional integration. Figure 12 shows the same axial map processed via Mean depth. That is inversely proportional to integration and proportional to RA (Relative Asymmetry) and RRA (relitivised Asymmetry). in these maps low values (low mean depth) are red going though the spectrum (yellow,green) to the highest value(blue). Observing the values we see they are roughly in agreement, this is a reasonable result, the method of computation are analogous. If we look closely we see some interesting deviances, firstly figure 12 shows the typical result of processing a large map - the core of the integration is drawn to the centre, this is much less apparent in the fractional map. After visiting the area some interesting facts can be identified in the new fractional map. In figure 11 the streets marked TTheobold StreetY and TClerkenwell RdY are highlighted as significant fractional integrators. This is generally absent in the mean depth map (figure 12), these two streets are by direct observation heavily used arteries for both pedestrians and traffic. This is significant in that this route is made from a number of near incident axial lines, which creates a significant distance in the traditional step depth model.

Clearly the case of Clarkenwell Rd and Theobold Street is a clear indicator of the success of the speculation of low angle of incidence routes lowering the step depth distance and so forming a artificial super integrator. This can be seen as a visual success of the angle of incidence algorithum used in fractional angular configuration.

Camden Rd is another road which fractional integration turns into a main integrator, is another route which is a main thouroughfare between Camden (to the left of the map) and Holloway Rd (to the North), this is again another area which traditional integration analysis fails to pick up on, yet in this case the route is maintained as a long axial line.

Pentonville Rd (see fig 10) finally provides an interesting area here with fractional angular configuration the road it self remains integrated but the roads directly connected are not overly over integrated, which happens with traditional integration.

In general the impression is that this form of fractional integration seems reduce the effect of radius. Axial lines are both integrated to the edge of the map and less favoured by being closer to the centre. This was an entirely unexpected result which has been observed on a number of processed axial maps.

Top row

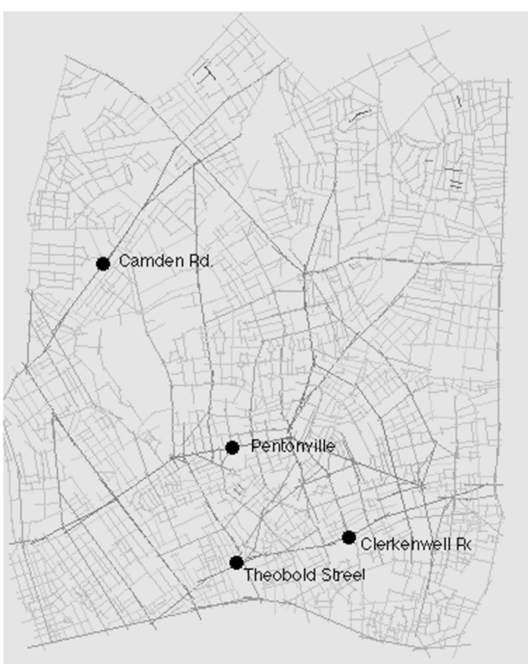
Figure 11. New York by log Mean Depth (left)

Figure 12. New York by log Fractional Mean Depth (right)

Bottom row

figure 11 Barnsbury fractional mean depth. (left)

figure 12 Barnsbury mean depth (right).



Further work

Complete observation studies

Clearly this work suggests the necessity of comparing results of fractional angular integration with traditional step depth integration. Step depth integration has proven to be a generally robust method which can be applied in a large number of cases, to be a clear successor fractional integration should be compared to a large number of real systems with statistically valid observational studies. Given the use of axial maps in both cases it should be a generally simple matter to reprocess old axial maps with new fractionally based software. To this end the Author and the Architectural Association permit use of the Meanda software freely for any academic research, please contact the author to obtain a copy of the software.

Remodelling

A secondary route would be redigitise axial maps with angularity as a consideration. For example it would be possible to split Oxford Street into a number of TsegmentsY, if the segments where touching but parallel, the movement from on segment to another would have zero depth change. It would then be interesting to observe if this kind of map produced any natural TsegmentationY, i.e. movement patterns changing up and down the length of the map.

Asymmetry

Meanda is certainly preliminary in its implementation of symmetrical angularity. It was mentioned in previous sections that angles were taken as the smallest angle from either side of the line. Introducing a system which could handle line intersection angles greater then 90 degrees would produce a system when the angle from line A to Line B would not necessarily be the same as from line B to line A. This asymmetry may introduce a number of interesting distortions in the fractional J graph which would lead to interesting changes in the fractional integration pattern.

Dvalue and Radius

Currently one of the most important numerical devices in the syntactical arsenal of tools is the concept of Radius and D-Value. Radius was largely derived from empirical studies showing in large systems that the best correlation with observed pedestrian movement came with a correlation with the measure of the average depth limited to 3 steps. This could be viewed in a number of ways, pedestrian journeys normally do not cross a city with out some other form of transport, so the notion of radius emerges as a way of limiting journey length to about that of the average pedestrian trip. Alternatively radius might be seen as a limit to the complexity of route someone is likely to take, pedestrians do not normally take on complex journeys.

How might this be applied to a fractional step depth? Firstly it might be possible to compute the integer step depth (number of changes of direction) and use this to limit the journey radius and then use this subset of the graph nodes to compute angular average depth.

If we take the second interpretation of depth, as a limit to how complex a journey someone might undertake, some arbitrary journey complexity of angle might be empirically uncovered (for example radius 2.6). Any radius greater than this might be ignored in the radius computation. This area definitely requires further study.

D-Value is another area where the integer nature of integration appears. The D-Value is an attempt to make different urban systems comparable, this becomes very important when compairing the same city over time. For example it is common in European cities to have a more complex medeival core which overtime becomes comparatively less integrated though the whole system. In London the old walled City of London is no longer the centre of the movement economy of the capital. To manage these complexities the D-Value attempts to reduce relativised RA by a constant (the D-Value) which represents how complex a diamond shaped graph of the same size would be. Given Fractional Angular Mean depth is largely working in units of normalised angle it seemed logical to avoid the use of the D-Value formula on the angular depth. Further work is clearly needed in the computation of an equivalent D-Value formula to permit the comparison of urban systems.

There might be a quick solution to both these problems by the use of fixed space count. For example if the radius measure said look at the average depth of the 50 closest spaces then for a system which was bigger than 50 spaces in total there would be a natural limit to the total depth of the system. This local clipped depth would be naturally comparable in absolute terms to any other fractional network which had a similar clipped to 50 radius applied, possibly only the form not size would emerge from this value.

Area overlap of convex spaces

When considering automatic computation of convex spaces such as generated by Spacebox then it is simple to observe that automatic generation of convex spaces tends to generate a number of spaces which have very high levels of intersection. A fractional system which involves computing objects with high areas of overlap with small fractional distances and areas of low overlap as high fractional values could be quickly built in a 'powerful' GIS system. Such an overlapping system would reduce the distortion of the configurational analysis by removing the artificial weighting of the core to the areas of the map with high shape counts.

The third dimension

One common naive objection to the value of a configurational study is the lack of the third dimension. The use of fractional integration could be applied to volumes (moving from a large open space to a small closet would be a significan step), but this would miss an interesting point. A more sophisticated objection would be to the possible influence of gravity to the movement economy of a city. Where pedestrian,cyclist or horse draw movement occurs (more common in historical cities) it would be natural of the population to prefer routes of zero height change. A simple extension of angular computation would lie with considering the 3 dimensional angle of intersection, in this case a route which climbed up an hill and then down, would have a larger value than a route, which might have a further metric distance, but would otherwise be largely flat. This could be applied to the movement of buildings where there tends to be a lower tendency to use the stairs to move from floor to floor so reducing circulation vertically. This would naturally require the complete rebuilding of an aixal line model so that each line occupies a three dimensional path.

Conclusions

It was proposed that some new forms of processing might help analyse certain situations where current forms of processing appear to be insufficient. It appears that fractional integration takes on the benefits of integration and introduces new and unexpected benefits such as a weakening of the effect of radius on large maps. It seems clear that fractional integration which takes change of angle into account can be used to produce an apparently new level of clarity into spatial configuration. While it would be premature to abandon current forms of axial processing, it does seem that the combination of axial line and angular fractional integration may be producing new levels of clarity. This work certainly seems to strongly suggest that further comparative work should be done examining the degree of correlation between fractional angular integration and observed movement.

If this work on fractional angular configuration proves to be a more accurate predictor of movement in urban situations. Then this would being to clarify how integration works, it would promote the thesis that people navigate in large scale systems by minimising changes in angle.

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