The Role of Space in the Emergence of Conceived Urban Areas

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Abstract. A city is usually made up of numerous different named areas but how these areas are defined is problematic. Lynch (1961) suggests that the sense of urban areas are mainly determined by thematic continuities consisting of spatial characteristics, such as the width of street, building type, colour, texture, façade detail and so on, and also gives a hypothesis that the image of urban area could be gradually developed and conceived through the network of sequences, a sense of interconnectedness at any level or in any direction. Rossi (1984) also argues that urban areas, identified as the study areas in his book, can be defined or described by their location in the city, their imprint on the ground, their topographic limits and their physical appearance which he sees as representing a consistent mode of living, involving a whole historic process of urban growth and differentiation. Both suggest, in effect, that there might be objective correlates for concepts of name areas, but little research since has taken this idea further. Here we ask if studies of cities as spatial configurations, using the techniques of space syntax, might throw light on these questions. Are there perhaps correlates between named areas and configurational properties? The paper first reviews syntactic methods applied in the past in defining different areas. These are for the most part based on spatial properties of the area itself, rather than the properties of the context, which prima facie seems likely to be a factor in how areas are defined. A new technique is then proposed for exploring properties of the context. Each axial line is taken as the root of a graph, and the numbers of axial lines found with increasing radius from the root is calculated, and expressed as a rate of change. This rate of change value is then assigned to the original axial line and expressed through bands of colour. The results show strong areal effects, in that groups of neighbouring lines tend to have similar colouring, and in many cases these suggest natural areas. However the areas defined vary with the rate of change at different radii, with larger areas being identified by large radii. This technique is applied to the central areas of Beijing and London, and the results compared to known named areas. It further visually compares the area structure sketched in the Lynch's case study of Boston with the area structure generated from spatial configuration of Boston, as a possible first step towards a cognitive dimension. Finally, it is suggested that what is being identified through this technique is not an area boundary in the normal sense, but what we might call a fuzzy boundary arising from the relation between the configurations of space within and outside the area. It further argues that the spatial definition of urban area could be more influenced by the external structure of the area, which might be called as exogenetic effect.

Keywords: Named Area, Space Syntax, Fuzzy Boundary, Exogenetic Effect.

1 Introduction

A city is usually made up of numerous different named areas but how these areas are defined is problematic. Lynch (1961) suggests that the sense of urban areas are mainly determined by thematic continuities consisting of spatial characteristics, such as the width of street, building type, colour, texture, façade detail and so on, and also gives a hypothesis that the image of urban area could be gradually developed and conceived through the network of sequences, a sense of interconnectedness at any level or in any direction. Rossi (1984) also argues that urban areas, identified as the study areas in his book, can be defined or described by their location in the city, their imprint on the ground, their topographic limits and their physical appearance which he sees as representing a consistent mode of living, involving a whole historic process of urban growth and differentiation. Both suggest, in effect, that there might be objective correlates for concepts of name areas, but little research since has taken this idea further. Here we ask if studies of cities as spatial configurations, using the techniques of space syntax, might throw light on these questions. Are there perhaps correlates between named areas and configurational properties? The paper begins with a background to syntactic methods applied in the past in defining different areas. These are for the most part based on spatial properties of the area itself, rather than the properties of the context, which prima facie seems likely to be a factor in how areas are defined. A new technique is then proposed for exploring properties of the context. Each axial line is taken as the root of a graph, and the numbers of axial lines found with increasing radius from the root is calculated, and expressed as a rate of change. This rate of change value is then assigned to the original axial line and expressed through bands of colour. The results show strong areal effects, in that groups of neighbouring lines tend to have similar colouring, and in many cases these suggest natural areas. However the areas defined vary with the rate of change at different radii, with larger areas being identified by large radii. This technique is applied to the central areas of Beijing and London, and the results compared to known named areas. It further visually compares the area structure sketched in the Lynch's case study of Boston with the area structure generated from spatial configuration of Boston, as a possible first step towards a cognitive dimension. Finally, it is suggested that what is being identified through this technique is not an area boundary in the normal sense, but what we might call a fuzzy boundary arising from the relation between the configurations of space within and outside the area. It further argues that the spatial definition of urban area could be more influenced by the external structure of the area, which might be called as exogenetic effect.

2 Syntactic Definition of Urban Areas

A number of syntactic studies in the past have begun to explore the nature of urban areas and have developed a series of techniques for identifying urban areas from the perspective of urban structure. Hillier (1987a, 1987b, 1989) suggested that the optimizing correlations between spatial configuration measured by integration and movement rates provided a powerful method for picking out sub-areas within a larger urban areas. Such kind of sub-areas within urban like district were named as "natural areas" whose structure can predict movement rates. Moreover, Hillier (1996) pointed out that the part-whole structure of cities lies in understanding the movement economy, that is, that under the condition of integration and density, urban grid initially shapes the pattern of movement, and then it further influences the patterns of land use and architectural density as a transmission by movement, which in turn maximizes movement and its by-product by spatial integration and then creates multiplier effects between them. And the part-whole problem could be approached by relations between the different radii of integration and related movement. Then, he

(1996) developed another technique for identifying urban areas that the correlation between global integration and local integration at the scattergram can be used to identify urban parts: the steeper slope of the regression line of sub-area across the regression line for a whole city could imply this distinctive sub-area. Based on which, he (1996:151) further argued that "places do not make cities, but it is cities that make places." In addition, he (1999, 2001) gave a syntactical definition of a city that a network of linked centres at different scales (from a couple of shops and a cafe to sub-cities) set into a background of residential space. With Hillier, Raford (2005) further developed the technique of correlation contour map, the continuous correlation transition between integration and movement as the boundary of sub-area changing, to distinguish sub-areas in the fragmented urban context. The first technique, together with Raford's correlation contouring, cannot differentiate physical area structure without the data of movement, and the second one ignored impacts of the relation between consecutive scales that might play import role in the formation of sub-areas.

Peponis (1989) also proposed another technique of decomposing towns into distinct sub-areas along the consecutive axial lines of the highest choice value that indexes how many of the most direct paths between all the possible pairs of other spaces go through a particular space. When the choice core, the line of the highest choice, bifurcates, the cutting lines go along the lines which could maximize the total choice value while minimize the number of the cutting lines. The implicit hypothesis of this technique could be that the boundaries between sub-areas act as arteries for through movements in towns that are a tenet of modern urban planning, such as neighbourhood unit by Perry (Perry, 1929), though Peponis gave the emphasis on that the formation of sub-areas did not arise from discontinuity and encloseness.

Read (1999, 2001) argued that the structures of Dutch cities were generated more from the conscious planning and design than from the spontaneous process, and as a result Dutch cities split themselves into the two distinct layers of supergrid, a network of streets carrying the longer distance movement in the whole city, and local area, the catchment for local scale movement and neighborhood activities. Then, he proposed two techniques to explain this biplex urban structure. One is the integration gradient map, picking out the streets with high integration values relative to other streets in proximity and then tracing streets of high integration gradient based on integration R3 or Rn through urban grid, as a way to highlight supergrid; the other is the area integration map, indicating the concentrations of high integration at the radius 3 through giving a line the average of local integration values of all the lines within a topological distance of two or three (or within a certain metric distance) from this line, as a way to distinguish areas. At the same time, he proved a good correlation between average local integration of areas and average activities within areas in Dutch cities. Furthermore, he (2005) developed to differentiate urban network as the diverse and overlapped grids or shells, including supergrid and areas as two lowest layers, and rail networks, identified by different speed and scale of movement, together with distinct space-time experience and rhyme within each. In this sense, the lines constituting supergrid, topologically clustered, were considered as a community at urban level, as the same as local areas as communities but at neighborhood level. It seems that these two techniques for identifying urban areas ignored the interfaces between spatial configurations crossing scales, but relied more on the effects of local spatial configurations, such as mean integration at the radius of 3, on the formation of local areas, and finally on local activities and movement speed to some extent.

Can the interfaces between spatial configurations at the consecutive scales define area structures in cities and then explain the process of their formations? Or, do urban areas of cities emerge from the process of the embeddedness of each space into its context? These questions could be approached in the context of the Hillier's centrality paradox that is that the more integrating the internal configuration of a convex form and then the more its most integrated internal zones is segregated from it external environment, that is called centrality paradox. He suggested that the urban transformation would be the sequence of the tension between internal and external integration in this way overcoming the centrality paradox (Hillier, 1996). Does it suggest that a named area as an object could be identified at the critical point where the lines constituting this area are least embedded into the urban spaces considered as their external environment, while radius rising up?

3 Relation of Node Count and Radius

Which syntactic variable could be used to indicate the process of embeddedness of urban space? A draft idea is first proposed. Each axial line (segment) is taken as the root of a graph, and the numbers of axial lines found k depth (or metric distance of k) away from the root is calculated, and then denoted as node count Rk of an axial line (segment). It approximately measures the degree to which an axial/segment is embedded into its surroundings at the radius k. Then, the rate of change value is assigned to the original axial line/segment across radii as a way to roughly demonstrate the process of how this line/segment is embedded into its neighbouring areas. For example, if randomly selecting a line in the axial map of London, and then computing its point depth at the radii of from 5 to 8 that picks out all other lines 5, 6, 7, or 8 depth away from that selected axial line respectively, we can approximately get node count R5, 6, 7, or 8 that demonstrate how large area this line respectively covers within the topological distance of 5, 6, 7, or 8 (Fig. 1). The rate of change of node count from R5 through R6 and R7 to R8 could illustrate how fast this line is embedded into its surroundings from radius 5 to radius 8 step by step. Then, does node count have any mathematical relation to radius that might rigidly explain the embeddeness of an axial line and even an area?

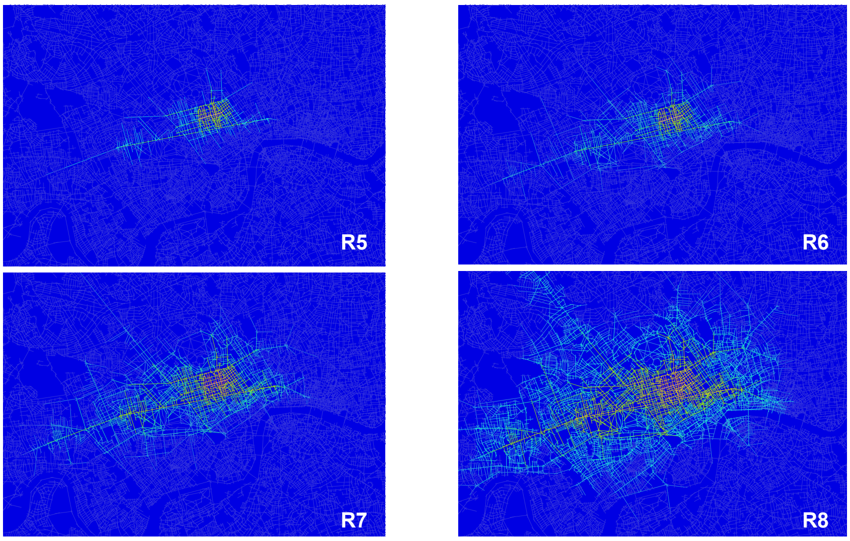


Fig. 1. Point depth from a randomly selected axial line

This question is approached by the case studies of Central London, East London and Central Beijing. First, all of them are large systems. The axial map of Central London has 17,320 lines and its radius-radius, that is equal to minimum mean depth in the system and demonstrates the radius at which the most integratest line might approximately reach at least one line at the edge of the system, is 10; East London having 28,225 lines and its radius-radius being19; and Beijing having 20,511 lines and its radius-radius being 10. Variety of samples could be selected from the central areas of these systems as a way to avoid the edge effect that node count value of the line near the edge of an axial map could be biased by the edge of this map. Second, the geometric features of these regions are very different in the sense that Central London is an organic and irregular structure, most parts of East London are modern developments since 19th century also with irregular grid, but Beijing is more like a traditional orthogonal structure, and this could set the analyses in more complex contexts and might get more general results. Then, it formulates the variable of the change rate of node count and then colours the axial map of Central London, East London, Central Beijing and Boston, as a way to explore their area structures might generated from spatial configuration.

3.1 Mean Node Count of a Whole Map

The study starts by exploring the relation between mean node counts of the whole axial map, average node counts of all lines in the map, and radius, in the cases of Central London, East London and Central Beijing, which could proximately show how an axial line in average is embedded into the surroundings.

When mean node counts of the whole map are plotted against radii in these three cases, it shows a curve within the range from radius 1 to the radius-radius that is the radius beyond which at least one line could reach the edge of the map, and an approximately linear relation between them within the range over the radius-radius. That curve within the range below the radius-radius however more correctly represents the relation between mean node counts and radius, because the edge effect caused by axial lines reaching the edge of the map could be removed as much as possible below the radius-radius. Then, the natural logarithms of these two variables are further plotted together, called radius plot, and then the linear regression line seems to appear within the certain radius ranges. In the case of Central London, for instance, there is a linear regression line within the range from radius 2 to radius 14, and adjusted R-square over 0.999. It is also true in the case of Beijing where a linear regression line comes out within the range from 2 to 12 and adjusted R-square over

0.999. It is a bit different in the case of East London where the linear regression line could be found in the ranges of 1 to 4, 2 to 11 and 11 to 40, also under the condition of adjusted R-square over 0.999 (Table 1). All these linear regression lines mostly lie within the range below the radius-radius so that these correlations had not been greatly impacted by the edge effects. Thus, it could be formulated as the following: Ln (Mean Node Count) = b + a (Radius), Radius is within the range of α to β .

Then, it can be transformed as:

$$MeanNodeCount = K \times Radius^{a} \qquad (Radius \in (\alpha, \beta))$$

The exponent of a can measure change rate of mean node counts of a region as radius rising up, and the constant K relates to mean connection of this region.

It might be suggested that mean node counts of a region, such as Central London, East London and Central Beijing, could have an approximate power law relation with topological radius within certain radius range, in which the parameter of a could indicate the average speed of all lines of a region topologically reaching surrounding lines as radius rising up.

Table1. Mean Node Counts & Topological Radius

Region	Radius Range1	a1	Radius Range2	a2	Radius Range3	a3
London	1,2	2.12	2,14	3.04		
East London	1,4	1.46	2,11	0.78	11,40	4.28
Beijing	1,2	2.03	2,12	3.17		

If using metric radius rather than topological radius, can we find the similar relation between node count and radius in these cases? In a segment map run on Depthmap, node count of a segment at the metric radius k can be defined as the number of all segments k meters (Manhattan distance) away from this segment. As for these three cases of Central London, East London and Central Beijing, the natural logarithm of mean node counts against the natural logarithm of metric radii from 100m to 10,000m, is plotted generated respectively, and then a linear regression line appears under the condition of adjusted R-square over 0.99 in all plots (Table 2). It means that mean node counts of these three regions could have a proximate power law relation with metric radius within certain radius range.

Table2. Mean Node Counts & Metric Radius

Region	Radius Range	a
London	10-10000	1.701
East London	10-20000	1.809
Beijing	10-10000	1.750

3.2 Mean Node Count in Area

Is there the similar kind of relation between mean node count of an area extracted from these three regions and radius? Several named areas and estates, whose boundaries have been described in the website of Wikipedian, many travel books or other planning documents, are selected in the centre of these regions to serve as the samples with little edge effect. For example, seven samples from Central London are Soho, Covent Garden, Mayfair, St. Jame's, Bloomsbury, Holborn and Marylebone; ten samples from East London are a luxury estate and a social housing in Surry Dock, three estates in Beckton, Poplar, a social housing estate in Limehouse, two social housing estates in the Isle of Dog, and Canary Wharf; seven samples from Central Beijing are Shichhai, Fengsheng, White Pagoda, Xintaicang, Wangfujing, Nanluogu and Dongdan which lie within the Inner City of Beijing. The numbers of axial lines of these named areas and estates are not either too big or too small, so that the size variance between these samples remains moderate. In the case of Central London, the maximum number of axial lines of areas is 164, the minimum 63 and the average 89.9; in the case of East London, the maximum is 153, the minimum 45 and the average 100.2; in the case of Beijing, the maximum is 167, the minimum 56 and the average 98.9.

The log-log radius plot is respectively drawn for each named area or estate in these three cases, and then the linear regression line is generated respectively within any possible radius ranges under the condition of adjusted R-square over 0.99. It seems that the logarithm of mean node counts of each area had the linear correlation with the logarithm of topological radius, and this indicates that there is a proximate power law relation between mean node count of an area and radius within the certain radius ranges. Table 3 shows the radius ranges in which the linear regression line can appear in the log-log radius plot for each area, as well as the slopes of the regression lines that could demonstrate average speed of the lines in an area topologically reaching the surrounding lines in the given radius ranges. On the one hand, in each case the different areas seem to have different radius ranges where a regression line appears in the log-log radius plot. For example, as for the case of Central London, Marylebone and Mayfair have the radius ranges of 1 to 2, 2 to 8, and 8 to 15, Soho has the ranges of 1 to 2, 2 to 9 and 9 to 14, Covent Garden and Bloomsbury have the ranges of 1 to 2, 2 to 8, and 8 to 14, Holborn has the ranges of 1 to 2, 2 to 10, and 10 to 15, and St. Jame's has the ranges of 1 to 2, 2 to10, and 10 to 16. It is the same as in the cases of East London and Central Beijing, though the radius ranges are different. On the other hand, the slope of regression line, denoted as a, changes a lot between the consecutive ranges in the same area, which could demonstrate the fact that there exist one or several big jumps in the average speed of the lines of this area reaching others across radii. For example, the slope of regression line of Canary Wharf in the East London case changes from 2.247 to 3.055, 2.417 and 3.963, corresponding to the consecutive radius ranges of 1 to 6, 6 to 10, 10 to 17, and 17 to 25. In other word, the graph of the plot-plot radius plot of Canary Wharf had three points of inflexion that are 6, 10, 17 where the tangent line of the graph suddenly changes much. Such inflexion points might show the 'boundaries' of an area where the extent of this area being embedded into its surroundings could fluctuate much. Thus, it might be concluded that mean node counts of an area could have an approximate power law relation with topological radius within the certain radius ranges that can be verified in the log-log radius plot. And it further suggests that the inflexion points in this kind of log-log radius plot might cast light on the differentiation of area structure.

Table3. Mean Node Counts of Area & Topological Radius (Continue)

Sub-areas from Central London

Area	Radius Range 1	a1	Radius Range 2	a2	Radius Range 3	a3
Marylebone	1,2	2.867	2,8	3.173	8,15	1.643
Mayfair	1,2	2.740	2,8	3.308	8,15	1.696
Soho	1,2	2.612	2,9	3.150	9,14	1.723
Covent Garden	1,2	2.663	2,8	3.216	8,14	1.746
Bloomsbury	1,2	2.581	2,8	3.347	8,14	1.703
Holborn	1,2	2.547	2,10	3.365	10,15	1.480
St.James's	1,2	2.434	2,10	3.153	10,16	1.635

Sub-areas from East London

Area	Radius Range 1	a1	Radius Range 2	a2	Radius Range 3	a3	Radius Range 4	a4
Surry Dock (LuxuryH)	1,2	1.663	2,12	2.869	13,24	3.943		
Surry Dock (SocialH)	1,3	1.578	3,8	2.995	9,13	2.034	12,25	4.194
Beckton N	1,2	1.585	3,30	2.544				
Beckton W	1,2	1.700	3,30	2.657				
Beckton E	1,2	1.700	3,30	2.657				
Limehouse (SocialH)	1,2	1.585	2,21	3.032				
Poplar	1,2	1.700	2,22	2.909				
Canary Wharf	1,6	2.247	6,10	3.055	10,17	2.417	17,25	3.963
NE_Isledog (SocialH)	1,2	1.807	2,7	2.832	7,14	1.777	15,27	3.799
NW_Isledog (SocialH)	1,6	2.803	6,15	1.527	15,27	4.007		

Table3. Mean Node Counts of Area & Topological Radius

Sub-areas from Central Beijing

Area	Radius Range 1	a1	Radius Range 2	a2	Radius Range 3	a3
Wangfujing	1,2	2.842	2,8	3.210	8,15	1.508
Dongdan	1,2	2.746	2,9	3.298	9,16	1.391
Nanluogu	1,2	2.661	2,10	3.171	10,17	1.335
Xintaicang	1,2	2.425	2,10	3.202	10,17	1.401
Fengsheng	1,2	2.228	2,9	3.545	9,16	1.588
Shichahai	1,2	2.122	2,9	3.559	9,17	1.632
White Pagoda	1,2	1.984	2,10	3.563	10,17	1.580

Based on the primary findings in the study of those three regions such as Central London, East London and Central Beijing, as well as 24 areas selected from the above regions, a hypothesis is posed that the logarithm of node count of an axial line could have a linear correlation with the logarithm of radius within the certain radius ranges, and this could be mapped as a log-log radius plot where a few inflexion points might be identified as a possible way to differentiate area structure in cities.

3.3 Node Count of a Line

In the following, axial lines are randomly selected from the axial maps of Central London, East London and Central Beijing, respectively, in order to test the hypothesis of an approximate power law relation between node count and radius within the certain radius range of α to β that could be formulated.
Ln (Node Count) = b + a (Radius), Radius is within the range of α to β.
Then, it can be transformed as:

$$NodeCount = K \times Radius^{a} \qquad (Radius \in (\alpha, \beta))$$

The exponent of a can measure change rate of node count of an axial line as radius rising up, and constant K relates to connection of axial line.

In each case, ten axial lines are selected as samples. Table 4 shows the radius range of α to β and the exponent of a for these thirty axial lines. It seems that node counts of these lines have an approximate power law relation with radius within the certain radius ranges less than radius-radius, and the exponents of a fluctuate much between the consecutive ranges. Although this experiment has not strictly and rigidly proved that hypothesis due to the small sample size, it could be suggested that the correlation between node count of an axial line and radius could reveal the extent to which an axial line is embedded into its context constituted by other lines through the configuration of urban grid, and this maybe provide a new way to identify area structure in cities from the syntactic perspective.

Table 4. Node Count of Line & Topological Radius (L*_Ln: Line * in Central London; L*_Eln: Line * in East London; L*_BJ: Line* in Beijing)

Sample	Range 1	a1	Range 2	a2	Range 3	a3	Range 4	a4
L01_Ln	1,10	2.674	10,16	1.077				
L02_Ln	1,5	3.097	5,12	1.820	12,17	0.616		
L03_Ln	1,2	1.948	2,6	4.332	6,12	2.090	12,16	1.025
L04_Ln	1,2	2.280	2,7	3.507	7,15	2.360		
L05_Ln	1,2	1.716	2,7	3.973	7,16	1.843		
L06_Ln	1,11	2.981	11,15	1.559				
L07_Ln	1,2	2.402	2,9	3.259	9,15	2.034		
L08_Ln	1,3	2.283	3,10	3.415	10,15	1.942		
L09_Ln	1,2	1.893	2,5	2.794	5,10	3.830	10,16	1.916
L10_Ln	1,2	2.322	2,3	4.159	3,15	3.474		
L01_ELn	1,2	1.415	2,7	3.324	7,16	1.677	16,29	4.297
L02_Eln	1,10	3.060	10,35	0.913				
L03_Eln	1,15	2.935	15,34	0.860				
L04_Eln	1,4	2.298	4,19	2.917	19,34	0.904		
L05_Eln	1,4	3.778	4,10	1.926	10,40	0.847		
L06_Eln	1,2	1.222	2,13	3.830	13,34	0.994		
L07_Eln	1,14	2.736	14,23	1.744	23,40	0.850		
L08_Eln	1,3	2.134	3,9	3.102	9,25	2.545		
L09_Eln	1,7	2.695	7,30	1.984				
L10_Eln	1,2	1.585	2,8	4.315	8,15	1.966	15,40	0.923
L01_BJ	1,5	3.000	5,10	1.307				
L02_BJ	1,3	1.550	3,9	4.930	9,14	1.977		
L03_BJ	1,2	1.138	2,8	5.533	8,14	1.646		
L04_BJ	1,2	1.848	2,7	4.556	7,12	1.913		
L05_BJ	1,3	1.441	3,8	5.521	8,11	2.710		
L06_BJ	1,2	2.433	2,8	4.303	8,15	1.141		
L07_BJ	1,9	2.764	9,14	1.235				
L08_BJ	1,2	1.684	2,9	3.740	9,14	1.297		
L09_BJ	1,5	2.889	5,10	4.228	10,15	1.381		
L10_BJ	1,8	2.994	8,13	1.338				

4 Areal Pattern by Spatial Configuration

Do axial lines or segments within the same urban area have same or similar change rate of node count with radius increasing? Since the exponent of a, that is equal to the slope of regression line in the log-log radius plot, can measure change rate of node count of an axial line, this question could be approached through the comparison of the values of the exponent of a of all lines in the whole region that could be made up of different urban areas. Then, change rate of node count of an axial line is defined by the exponent of a in the following:

$$Emd(k) = a(k) = Log(NC\_k \div NC\_k - 1) \div Log(k \div (k - 1))$$

Emd(k) denotes change rate of node count of an axial line at the radius k, to measure the extent to which this axial line is embedded into urban grid at the scale of radius k. Variable of a(k) denotes exponent a at the radius k, and NC_k denotes node count of an axial line at the radius k.

If the values of change rate of node count are only compared between all lines at the certain radius of k, the value of Log(k/(k-1)) becomes the constant for each line because k is the same for every lines. Thus, the formula could be transferred into the following:

$$Emd(k) \sim Log(NC\_k \div NC\_k - 1) \sim NC\_k \div NC\_k - 1$$

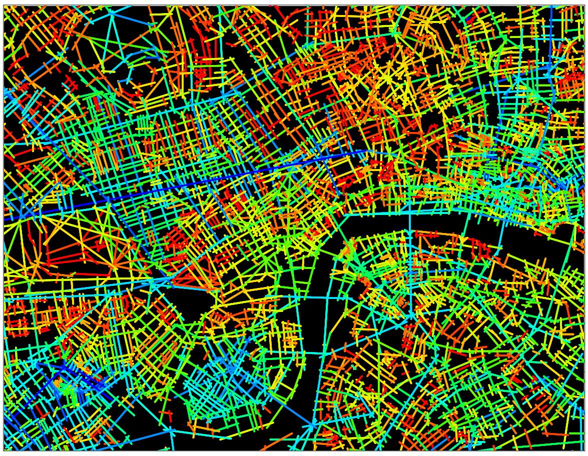
It means that change rate of node count of an axial line can be measured by the node count at the radius k divided by the node count at the radius of k-1.

As to the segment model, the similar formula was developed to measure the extent to which a segment is embedded into urban grid at the certain metric scale.

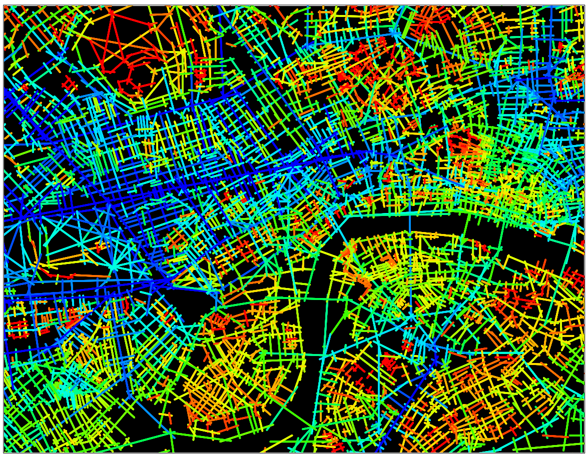
$$Emd(k\_m) \sim Log(NC\_k \div NC\_m) \sim NC\_k \div NC\_m$$

Emd(k_m) denotes change rate of node count of a segment from radius k to radius m, and NC_k denotes node count of a segment at the radius k.

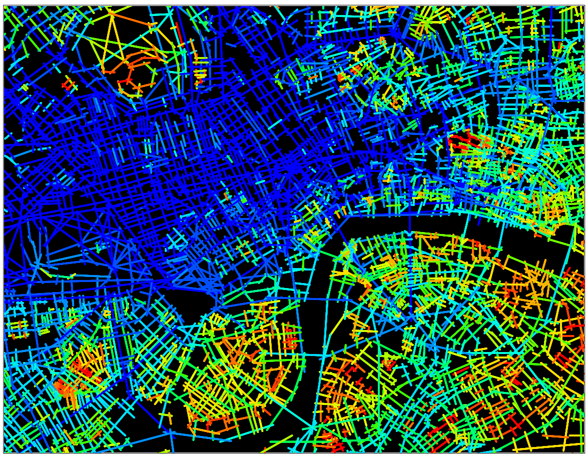
Can these simple formulas be used as a technique to visually differentiate the area structure of cities? Could areal effects be generated by colouring axial lines or segments in terms of the value of Emd(k) or Emd(k_m) ? First, Emd(k) or Emd(k_m) is assigned to each axial line or segment in Depthmap, and then the whole axial map or segment map is exported out and then is imported into Mapinfo. Second, each axial line or segment is coloured from red to dark blue according to its value of Emd(k) or Emd(k_m) crossing radii, the red indicating higher change rate of node count and the blue indicating lower one. Finally, a series of pictures are generated to reflect the degree to which all axial lines or segments are embedded into urban grid at the certain scale. If this technique is applied to the central areas of Beijing and London, the results show strong areal effects, in that groups of neighbouring lines tend to have similar colouring, and in many cases these suggest natural areas. However the areas defined vary with the rate of change at different radii, with larger areas being identified by large radii (Fig. 1- 4).



Area structure generated by Emd(5)

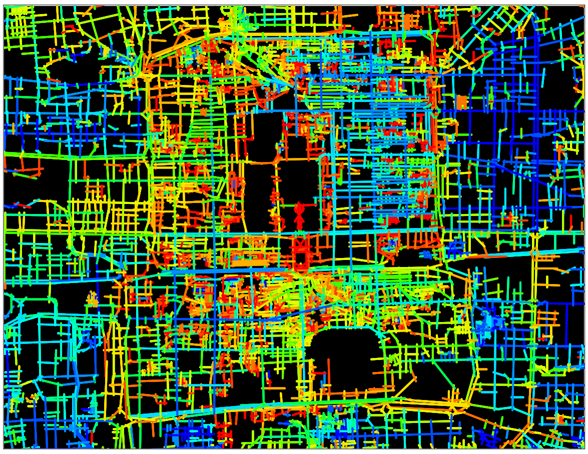


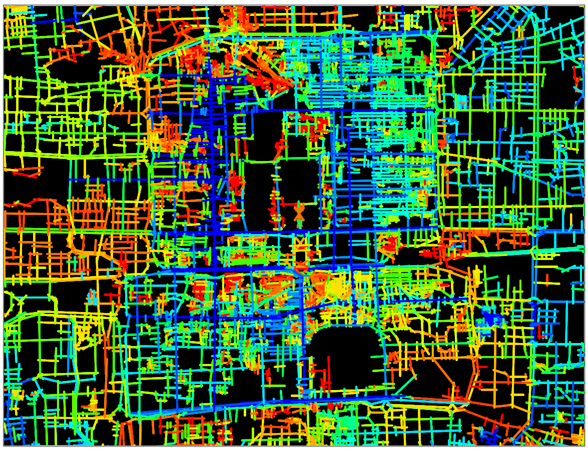
Area structure generated by Emd(7)



Area structure generated by Emd(10)

Fig.2. Area Structure of Central London Generated By Change Rate of Node Count Rk (Emd (k))


Area structure generated by Emd(5)


Area structure generated by Emd(7)

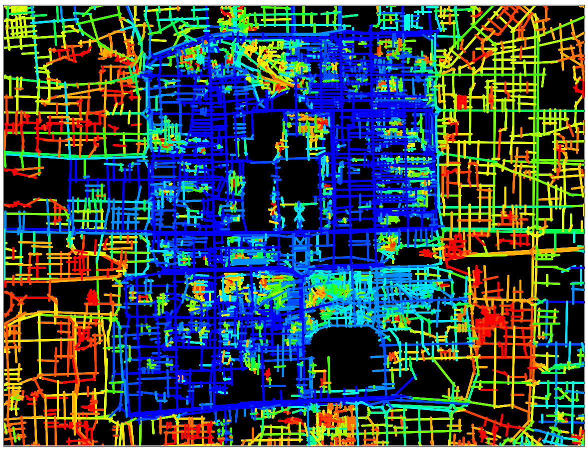
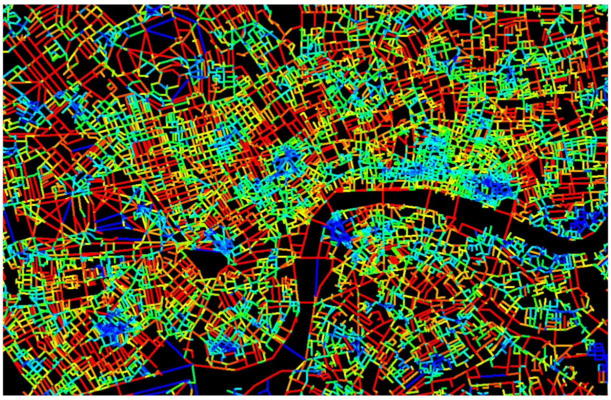
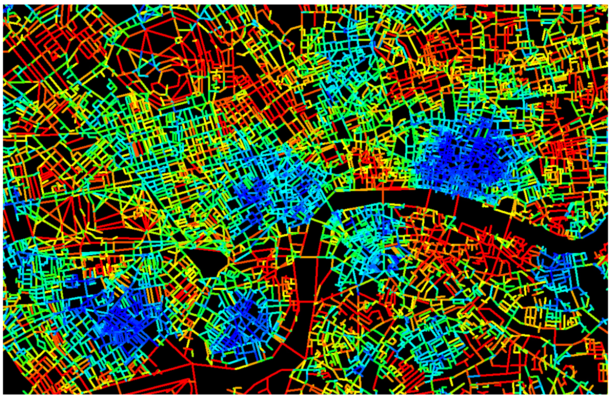

Area structure generated by Emd(10)

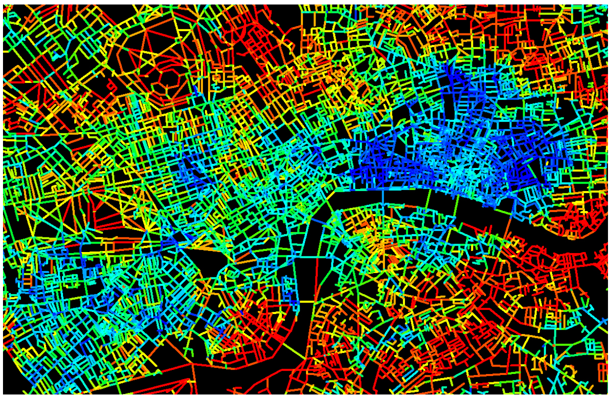
Fig.3. Area Structure of Central Beijing Generated By Change Rate of Node Count Rk (Emd (k))



Area structure generated by Emd(600_800)

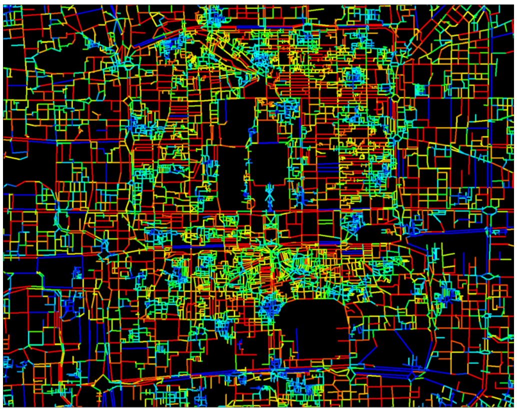


Area structure generated by Emd(1600_1800)

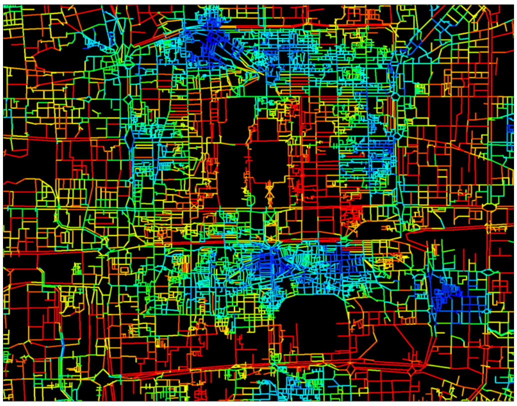


Area structure generated by Emd(2800_3000)

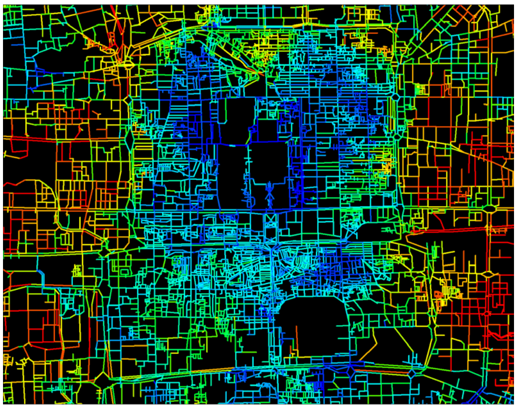
Fig.4. Area Structure of Central London Generated By Change Rate of Node Count at Metric Radius k (Emd (k_m))



Area structure generated by Emd(800_1000)



Area structure generated by Emd(2000_3000)



Area structure generated by Emd(8000_9000)

Fig.5. Area Structure of Central Beijing Generated By Change Rate of Node Count at Metric Radius k (Emd (k_m))

4.1 Place Name and Area Structure

Do these pictures of area structure of cities correspond to the reality of area structure in cities? The known place names are used as a first but imprecise step towards understanding and representing spatial aspects of area structure in Central London and Central Beijing. Place names had been coined by our ancestors as descriptions of urban areas in terms of their situation, use, appearance, topography, ownership or other association (Mills, 2001), and they might produce evidence of the deepest layers of urban structure (Rossi, 1984). The area structure identified by place names is visually compared to the picture of the area pattern produced by the variable of Emd (k) or Emd(k_m). However, place names are historically defined, and their relation to cognition is still unknown and also is not the objective of this paper. This comparison between the area structure generated by spatial configuration and that marked by place names has no cognitive implication.

In the cases of Central London and Central Beijing, the axial map coloured in terms of the value of Emd(5), under the background of that radius-radius of these two maps is 9, seems to visually correspond to the named areas to some extent, whilst, the segment model of London coloured according to Emd(1,000_1,200) and that of Beijing coloured according to Emd (1,000_1,500) seems to visually correspond to the named areas to some degree. (Fig.5-Fig.8). It might hint that the change rate of node count at the certain level could more or less play a role in the formation of the area identified by place names.

Moreover, the area covered by the axial lines 4 topological depth away from the axial line at the least integrated line of a named area is larger than this named area, whilst the area covered by the segments 1,000m away from the segment at the centre of a named area is larger than this named area. It might suggest that these areas identified by place names could be shaped by Emd(k) or Emd (k_m) that is the change rate of node count at the radius at which some lines/segments counted as node count are outside the boundaries of these areas. Since the lines/segments both inside and outside the boundaries are involved in the calculation of Emd(k) or Emd (k_m), it might imply that these named areas could be generated more or less by the relation between their internal structure and their external structure measured by the change rate of node count. On reflection, the value of Emd (k) is more affected by the new added lines from the radius k-1 to k, and Emd (k_m) more influenced by the new segments from the radius k to m . In these two cases, Emd (5) is affected by the new lines added from the radius 4 to 5, but the lines 4 depth away from the least integrated line of a area is outside the boundary of the area. The value of Emd (1,000_1,500) also reflects the same fact. It might imply that the definition of urban area could be more shaped by the external structure of the area.

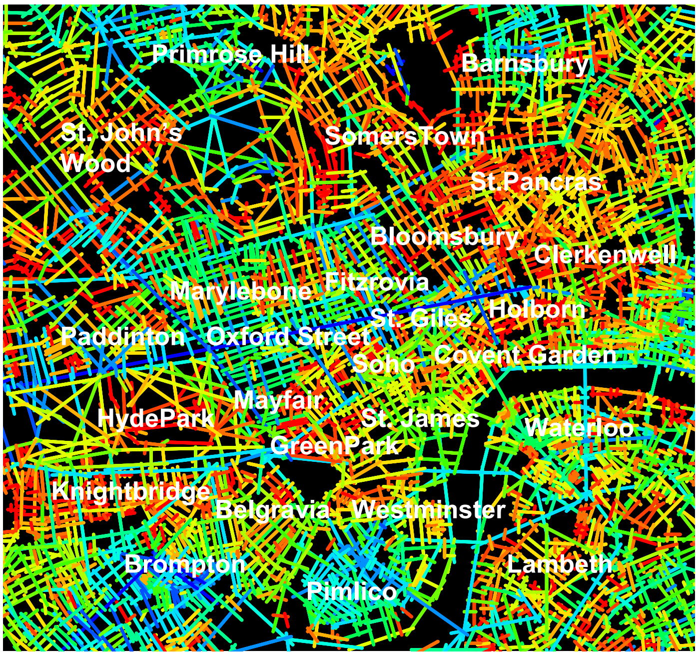


Fig.6. Axial Map of Central London R5

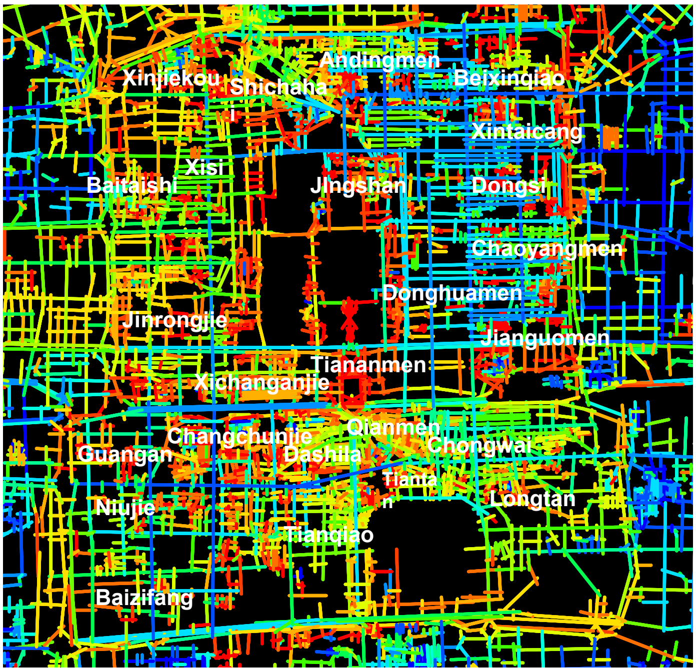


Fig.7. Axial Map of Central Beijing R5

Fig.8. Segment Map of Central London 1,000m-1,200m

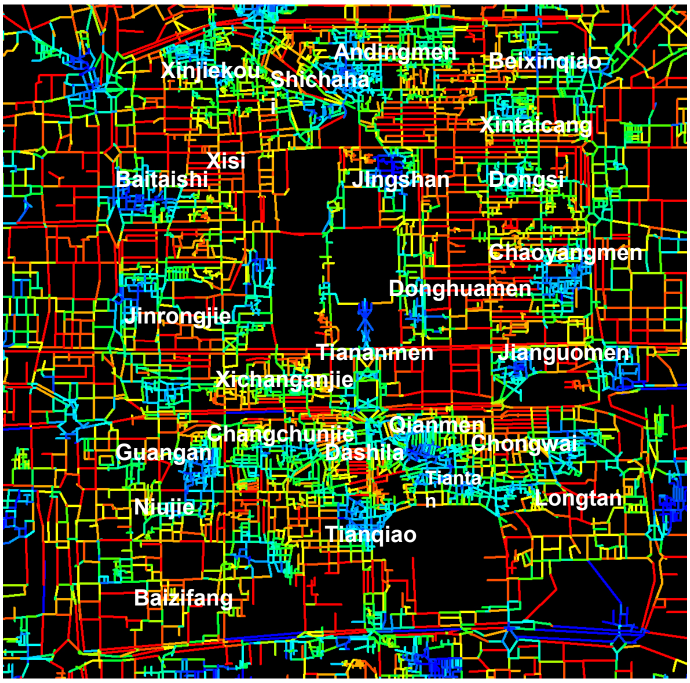


Fig.9. Segment Map of Central Beijing 1,000m-1,500m

4.2 Boston Case

Lynch (1961) used the sketch map to record how people read cities from the perspective of cognition, and then identified that district, namely urban area, is one of five key elements of the image of cities perceived and conceived by people. He showed two kinds of boundaries of urban areas in the sketch map by outlining the maximum extent assigned to any district, and the hard core of common agreement. Such urban areas outlined in his sketch map of Boston can be compared to the pattern of urban areas of Boston generated by the variables of Emd(k) or Emd(k_m), which might cast light upon the role of spatial configuration in the conceiving urban areas.

Fig.9 and Fig.10 show the axial map coloured by the variable of Emd(4) and the segment map by the variable of Emd (700_800), and both are superimposed by the hard core of urban areas, denoted by solid line, identified in the Lynch's sketch map; whilst, Fig.11 and Fig.12 demonstrate the same axial map and segmental map, but superimposed by the maximum extent of urban areas, denoted by doted line, also distinguished in the Lynch's sketch map. In general, it seems that many hard cores of urban areas visually have good correlates to the area patterns in the axial and segment maps, whilst some of the maximum extents of urban areas have a reasonable correlates to the area patterns in the axial and segment maps. The primary finding could be that spatial configuration measured by change rate of node count within the certain radius range might play a role in the differentiation of area structure of the sketch map of Boson by Lynch. In addition, As the area covered by the axial lines 4 topological depth away from the axial line at the most integrated line of an urban area is larger than the boundaries of this area in this case, whilst the area covered by the segments 800m away from the segment at the centre of an urban area is larger than the boundaries of this area, it might be further suggested that what is being identified through this technique is not an area boundary in the normal sense, but what we might call a fuzzy boundary arising from the relation between the configurations of space within and outside the area.

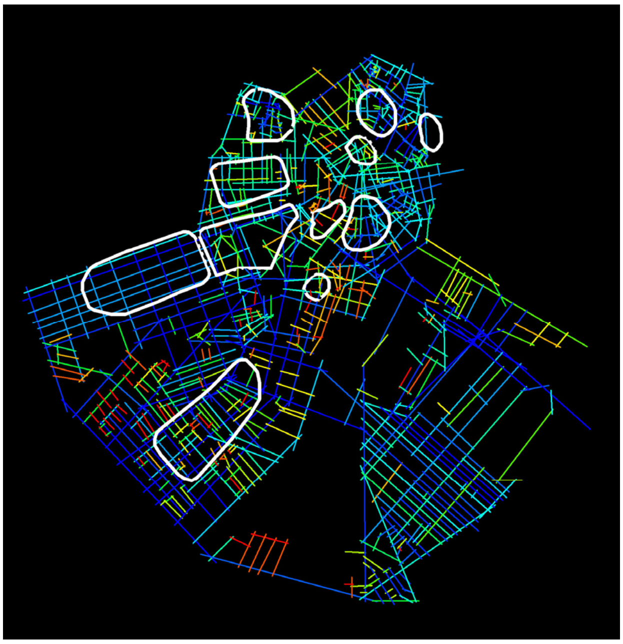


Fig.10. Axial Map of Boston R4 and Hard Core of Common Agreement

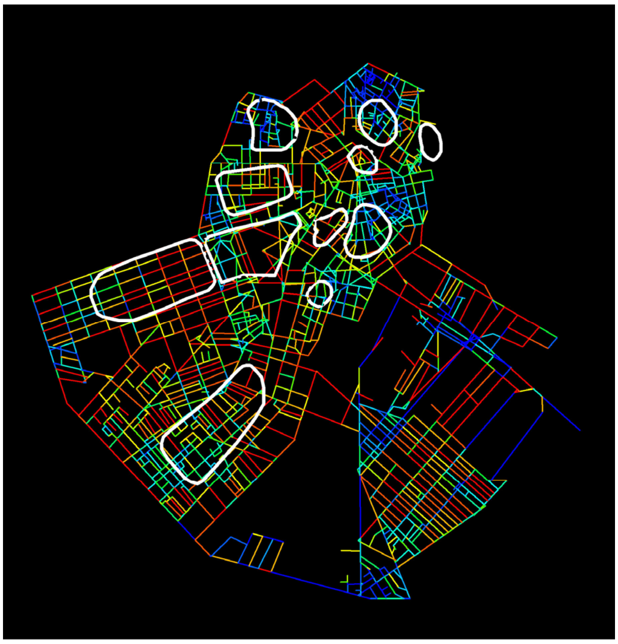


Fig.11. Segment Map of Boston R700m-800m and Hard Core of Common Agreement

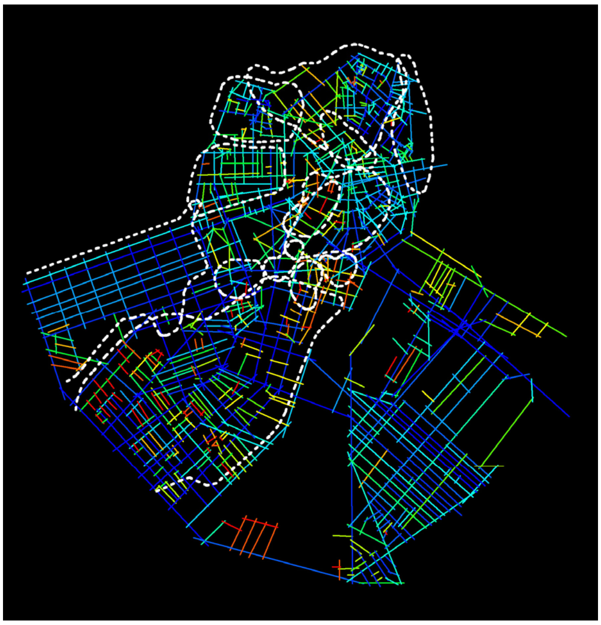


Fig.12. Axial Map of Boston R4 and Maximum Extent of Boundaries

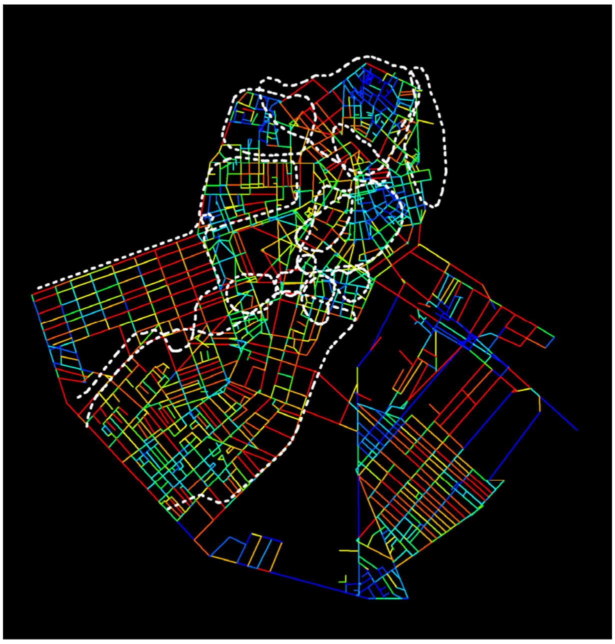


Fig.13. Axial Map of Boston R700m-800m and Maximum Extent of Boundaries

5 Conclusion

Through the case studies of Central London, East London and Central Beijing, it might be concluded that node counts of an axial line could have an approximate power law relation with radius within the certain radius ranges that can be verified in the log-log radius plot. And it further suggests that the inflexion points in this kind of log-log radius plot might cast light on the differentiation of area structure. Moreover, the areal effects of cities could be generated by the variables of the change rate of node count at the radius k in axial map, denoted as Emd(k), and the change rate of node count from the radius k to the radius m in segment map, denoted as Emd(k_m). Moreover the area patterns vary with Emd(k) or Emd(k_m) at different radii, with larger areas being identified by large radii.

Through the case studies of Central London and Central Beijing, the pattern of area structure generated by Emd(k) or Emd(k_m) seems to have some correlates to the area structure distinguished by place names, which might imply that spatial configuration could more or less play a role in the formation of the area identified by place names.

In the case studies of Boston, it could hint that change rate of node count also might account for the conceiving boundaries of urban areas in the Lynch’s study. In addition, it could also be suggested that fuzzy boundaries of area structure is being identified by Emd(k) or Emd(k_m) are shaped by the relation between the configurations of space within and outside the area.

It might be suggested that urban area could be spatially differentiated by the relation between its internal structure and its external context. As Hillier (1996:151) argues that “it is cities that make places”, the spatial definition of urban area might be more influenced by the external structure of the area, which might be called as exogenetic effect.

Acknowledges:

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