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MEASURING AND VISUALIZATION OF SPATIAL CHANGE USING INFORMATION ENTROPY

Beyazıt square case area in Istanbul

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ABSTRACT

Tobler's (1970) First Law of Geography states that nearby things are more related than distant things. In other words, there is a close relationship between nearby things compared to distant things. This also implies that built form is in a relational process in its topologic embodiment and the overall spatial form emerges a certain degree of wholeness. Mediating C. Alexander's (2002-2005) "levels of scale" property as a morphologic translation interface and using Shannon's Entropy (1948) concept as a data-mining method, this study allows revealing the degree of uncertainty and disorderness that a certain spatial complexity embodies. Shannon's Entropy, a method of measuring the information, has been employed in this study in measuring the state of uncertainty and disorderness conveyed through the multi-scalar context of built configuration across scales. Results have been hypothesized to correlate to the degree of wholeness, in other word completeness, of the case built area. Beyazit Square with its 50 hectare environs in the Peninsula of Istanbul has been selected as the case area due to the remarkable change that the square experienced through a harsh urbanization over the last sixty years. Building footprints belonging to two time periods have been used as raw data. Multi-scalar analyses conducted upon the data of 1946 and 2013 revealed that the wholeness of the square has deteriorated, almost halved, from 0,32bit to 0,63bit entropy level within last sixty years. This finding is being verified by the remarks of the spatial assessments done for the square and visualized by entropic interaction way of spatial modelling.

KEYWORDS

Wholeness, completeness, entropy, change, relationality

1. INTRODUCTION

It is due to our cultural context, maybe even due to our natural state of being alive, that we admit more value to life than a machine. We are biased. The distinction between machine and life boils down to the question of reproducibility. Only because we humans can dis- and reassemble a car makes it a machine? Is it too simple to be a system that has more value than the sum of its parts? The reason why a living organism is dead when disassembled and does not come to life anymore when reassembled is that first; we're not able to disassemble without destroying it and second; living organisms, like ourselves, can be seen as an ongoing self-maintaining process. Once stopped, it would need to restart from the very first cell division to become alive again. That's how we actually reproduce ourselves. Mehaffy and Salingaros (2011) state that there is no way to decompose an organism into its parts without destroying the connective networks -subsystems- that make the whole system work.

There are pros and cons of applying the notion of a "living" and therefore biological organism to a city. One concern to point out here: Similar to biological organisms can't we reassemble a city? Practically, we can! The "city life" wouldn't be exactly the same as before, but there would be a life. Even in a city that has not been destroyed and reassembled, public life changes every day. Therefore, there is a loose relationship between wholeness and life. The notion of wholeness is too closely tied to the concept of life. It has been asked at what point a human being mentally and physically conceives itself as a whole. There are so many ways of being incomplete as a person and still being alive, that the entire question of wholeness is a large, flexible and not so clear phenomenon. In the middle ages a city without basic elements such as a wall protecting it, was not a city. Then the entire definition of spatial wholeness and so the notion of "living structure" appears to be a matter of time, space and cultural relevancy.

By all means, the question of "city as a matter of wholeness" will not make any common definition for everyone since it is not as purely intuitive as Alexander suggests. Even a catalogue of the 15 properties that Alexander structurally defines for his definition of wholeness doesn't sound complete. It becomes misleading when conceiving wholeness as a solely physical property. Either spatial or functional, wholeness, as an urban spatial quality, requires a comprehensive looking on physical, cultural and mental everything what makes a "city". Therefore, questioning the notion of wholeness out of two-dimensional spatial data, through referencing Alexander, seems formally correct yet a highly debatable attempt.

Place is an adaptive cultural process. It may be incomplete or imperfect and yet can have a life. Adapted to spatial analysis, the question might be phrased as: how whole or how complete is a space or an area based on the information conveyed through its various, multi-scalar, morphologic possibilities? Shannon's entropy (1948), (2001) as a measure of uncertainty for conveyed morphologic information, is a consistent way to apply as the core data mining method in this study.

1.1 THEORY OF WHOLENESS

Alexander's overall idea of wholeness and life stands on a strong assumption of completeness. The wholeness of a built system is not about the quality and behaviour of each single entity what Alexander calls "centre", but about the way they come together and therefore make each other strong across scales. This implies an emerging and holistic sense of completeness about the relative size, shape and density of centres in making a greater whole. This was one of Alexander's major questions to himself in seeking of any structural features that tend to be present in those systems with more life (Alexander, 2002-2005, p. 144). He thinks that everything that has wholeness has also life and vice versa. Yet, the question arises around the need for a quantifiable definition of wholeness. It is obvious that Alexander's definition of wholeness as a phenomenon is highly related to the concept of order. Yet, this is not a shallow understanding of order that only exists in the nature but a quality that may exist in everything.

At the end of intensive studies on the phenomenon of wholeness, Alexander distilled fifteen structural features that he thinks are the ways every possible sub-component in a system, he calls centres, come together and make each other strong so that the whole system generates a certain degree of wholeness and life. Alexander's fifteen properties of wholeness are (1) levels of scale, (2) strong centres, (3) boundaries, (4) alternating repetition, (5) positive space, (6) good shape, (7) local symmetries, (8) deep interlock and ambiguity, (9) contrasts, (10) gradients, (11) roughness, (12) echoes, (13) the void, (14) simplicity and inner calm, and finally (15) non-separateness (Alexander, 2002-2005, pp. 244-289). Properties are the elaborative explanations of observations that were recorded in Timeless Way of Building (Alexander, 1979, p. 242). A "property", as a relative quality, in Alexander's texts, is a fundamental informative characteristic for wholeness and life (Waguespack, 2010). Alexander in this respect states that 90% of our human feelings are shared, and idiosyncratic parts which vary from people to people only account for 10% (Alexander, 2002-2005) and claims that human feeling is a legitimate instrument for recognizing the wholeness. However it is still intuitive and pseudo-scientific which yet needs scientific confirmation (Marshall, 2012).

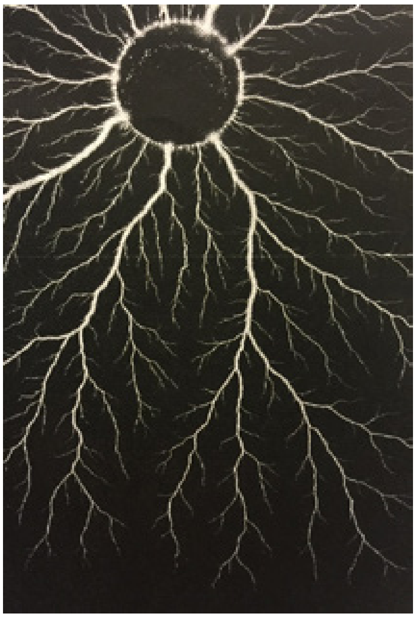

Figure 1 - Electric Discharge in an Electric Field (Alexander, 2002-2005, p. 247)

In order to understand "levels of scale" property in a comprehensive way, one may observe how an electric discharge in an electric field motion occurs and vanishes in a rush to recreate itself as in Figure 1. There is a recursive behaviour that repeats and brings itself into a new order through strongest to weakest zones in an everlasting way. Levels of electric zones create gradients and echoes through alternating repetitions as the integral parts of a robust whole. Alexander notes that it is not hard to see that in any system where there is a good functional order, there is also a good spatial coherence with a legible hierarchy (Alexander, 2002-2005, s. 246). In such hierarchy, the interplay among one level or size tends to be in a topo-geometric relationship with the nearest structural context.. Tobler (1970) in "First Law of Geography" states that nearby things are more related than distant things. In other words, there is a close relationship between nearby things compared to distant things. This also implies that built form is in a relational process in its topologic embodiment and the overall spatial form emerges a certain degree of wholeness.

A structural complexity can be more or less alive depending on the degree of wholeness it has (Alexander, 2002-2005). Early major attempts to measure the wholeness of things or systems analytically were "Gestalt Psychology" (Köhler, 1947) and "Quantum Physics" (Bohm, 1980) in which wholeness mathematically is defined as a recursive physical structure. Alexander (2002-2005) in this respect noted that there was no mathematical approach at that time to unearth the meaning of wholeness embedded in things and reflectively in human psyche (Jiang, 2017). In brief, Alexander described wholeness as a phenomenon in profound details and widest perspective that no other approach has done before.

2. DATASET AND METHOD

Alexander's assertions require scientific confirmation and this study raises the question of whether or not we can analytically measure Alexander's definition of wholeness or completeness using "Shannon's Entropy" (Shannon, 1948). In other words, this study develops a mathematical model of wholeness through generating the entropy for particular pixel levels out of building footprints raw data. Scale level in the proposed method refers to the varying pixel categories in data-mining. Scale in this kind of information retrieval process acts as a dynamic grid interface with equally divisible units upon any area's raw data. Size of the grid units are dependent on the number of pixels that are framed for each scale level as seen in Figure 2 below. In other words, for each scale level, the area is overlaid by a different grid in which each equivalent unit frames a different pixels density and thus a different morphologic formation. Eventually, in each scale level, through varying morphologic formations framed by each unit, varying entropy values are calculated throughout the grid as in Figure 2 below.

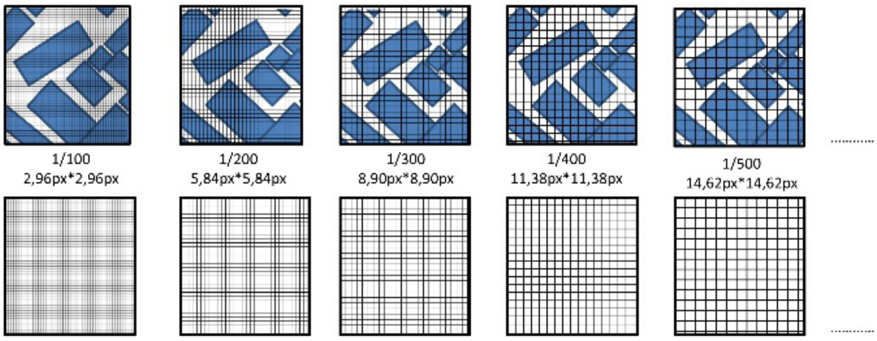

Figure 2 - Scaling the Grid and Thus the Number of the Pixels Framed by Each Grid Unit

This study, using Shannon's information entropy theory, develops an alternative quantifiable approach that can measure the contextual nature of completeness for a built environment from the scale levels point of view. In order to achieve it, a spatial analysis tool has been developed by using two major programming languages; "C#" developed by Microsoft (2015) and "Processing" developed by Ben Fry and Casey Reas (Jones, 2010). The tool has two major functions: 1) Data-mining and 2) Data-visualization. Data-mining function has been developed by compiling diverse image processing algorithms on C# to retrieve data via a hybrid feature extraction algorithm out of building footprints' raster data. Data-visualization function visualizes the retrieved data sets and illustrates the outcomes of the analysis. For this case analysis, building footprints vector data, for 50 hectares (500.000 m2) urban areas with 1024x1024 pixels resolution, has been selected as raw data. For two different configurations belonging to two different time periods, -1946 and 2013-, as seen in Figure 6, two different cumulative Entropy-IQR values have been generated via 10 different grid scales.

Statistical entropy was first introduced by Shannon (1948), (2001) as a basic concept in information theory, measuring the average missing information on a random source (Jat et al. 2007). Shannon's entropy originated from information theory as a measure of uncertainty of conveyed information over a noisy channel (Bailey, 2015), (Jat et al. 2007). The larger the value of Shannon's entropy, the higher is the uncertainty of information conveyed. Shannon focused on how to minimize the loss of information in revealing a message in another point. Entropy (H), in this sense, is a measure of information. H is dependent on the number of information categories, K. Higher the amount of data categories conveyed by an information, less probability of the same type of category to gather. It is also the least predictable state (Bailey, 2015), (Waguespack, 2010). Therefore, the entropy is always towards most probable or most likely state. By the same logic, the higher the spatial entropy, the more the uncertainty is, hence a larger potential towards change. Bailey (2015) states that Shannon's entropy is content-free and can be applied to measure any type of data with a multiplicity of information.

Shannon entropy is a quantity measuring the relations in a data category. Use of logarithm makes this quantity growing linearly with system size and "behaving like information". Shannon in his original paper states that the logarithmic measure is more convenient since it is mathematically suitable in measuring the number of possible states in which a system can be found. The unit of entropy is a "bit" (Wang, 2016). As it is distilled from diverse definitions of wholeness and Alexander's assertions (Alexander, 2002-2005, s. 64, 72, 77, 78, 112, 122, 144, 145, 146) it is possible to say that low entropy implies a relatively higher degree of wholeness (Shannon, 1948), (Leibovici, 2009).

Starting from Alexander's views on wholeness, the ultimate purpose of this study is to develop a mathematical model to unearth the degree of spatial uncertainty of a particular built area in relation to its immediate context. Using entropy in this sense, helps measuring the complex and multivariate information of two dimensional morphologic layout conveyed through the units of a grid system superimposed upon the analysed area. Entropy (H) by definition is a configuration-dependent concept. It is the measure of uncertainty that each unit holds considering of eight adjacent units' total built probability (P) as illustrated in below Figure 6. G is the built probability specific for each unit area, while the entropy is generated for the units that are adjacent to eight units, as illustrated in Figure 6 below. In brief, H is a measure emerged through the relative morphologic state of adjacent unit areas.

Recent studies (Karlström & Ceccato, 2002), (Li & Reynolds, 1993), (Li & Huang, 2002), (Maitre, Bloch, & Sigelle, 1994), (Tupin, Sigelle, & Maitre, 2000), (Claramunt, 2005) about use of information entropy in measuring the multivariate distribution of spatial co-occurrences is progressive (Leibovici, 2009). When reviewing the previous research on this field, the core struggle that emerges is about generating the entropy for the same context yet with different spatial configurations. Leibovici (2009), in this respect, notes that there is still a need for a coherent methodological approach that will consider the relatedness of constituting elements as an adjacency factor among the analysed data category.

Advancing the aforementioned progress on measuring the entropy of spatial complexities, this study develops a progressive approach. Referring to Leibovici's (2009) suggestion, the method is built on the ability of considering the nearness and relatedness as adjacency factors among the analysed units of various grid scales. As seen in Figure 2 above, the tool developed for this research enables running the analyses for various scale levels. For the case study in this paper, the analyses have been conducted for the grid scales from 1/100 to 1/1000 with regular intervals of 100. The way each single unit interacts with its eight adjacent units mathematically accounts in the calculation of entropy for each unit area except those by the grid edges. This leads to create a kind of highly varied data with varying spreads or deviations. In order to measure it, the multivariate nature of such data requires a discretization to eliminate the divergences.

IQR (Interquartile Range) is a statistical data measuring method that does a discretization for the data with varying spreads. It arranges the values from the smallest to the biggest. For discretization of the deviations along the data, IQR plays a role to extract the "middle fifty" where it draws a specified data as graphed using the Box and Whisker Plot in Figure 3 below. The extremes of the data are eliminated and it is where the bulk, middle fifty, of the data falls into. It is preferred over many other measures of spread in statistics when reporting about multivariate data sets. Due to fact that each output is scale-dependent, the ranges of the quartiles change as the scale of the analysis changes. In other words, each IQR for a specific scale relies on the changing morphologic states that are framed by different size of grid units. By the IQR method, each output data is reduced to a single value. Multiple analyses for varying scales allow generating multiple IQRs. Total sum of Entropy-IQRs that have been generated for diverse scale levels give the final outcome of the analysis.

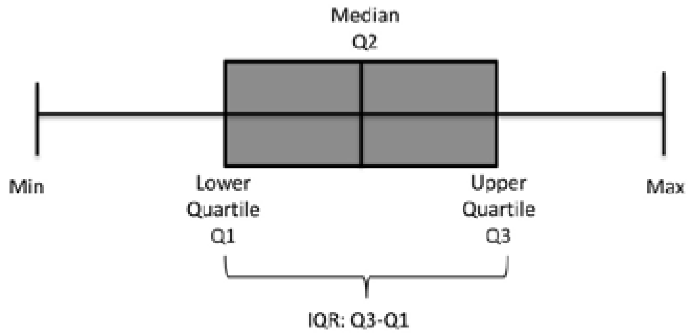

Figure 3 - Generating the IQR Value through Box and Whisker Plot

Referring to Shannon's entropy as formulated in below Equations 1, 2 and 3, for the ith unit of n units grid system, Gi is the unit-specific built portion where Pi value, considering the eight adjacent neighbour units' G values, is a relative value for built probability considering the adjacent units. Hi is the entropy for the ith unit and it is calculated as long as the unit is adjacent to eight surrounding units as seen in Figure 4 below. In other words, the units by the grid edges are exempted in entropy calculation.

$$G_i = \frac{Built\ portion\ of\ pixel\ i}{Total\ pixel\ area} \quad (1)$$

$$P_i = G_i / \sum_i^l G_i \quad (2)$$

$$H_i = P_i \cdot \log\left(\frac{1}{P_i}\right) \quad (3)$$

Equations 1, 2 and 3: G, P and H Calculations Using Shannon's Entropy

Each grid unit in Figures 6 and 7, matches a particular space and thus a particular portion of morphologic occurrence represented by a G value. Algori   assigns G=0 when the unit area is totally unbuilt, and G=1 when it is fully built up. Entropy (H) for the non-edge units, those interact with eight immediately adjacent ones, as in below Figure 6 are calculated. Unit number 5 in Figure 6 below is being surrounded by 8 adjacent units. The entropy (H) for the unit with G5 built density value is calculated by considering G5 with G1, G2, G3, G4, G6, G7, G8 and G9 values.

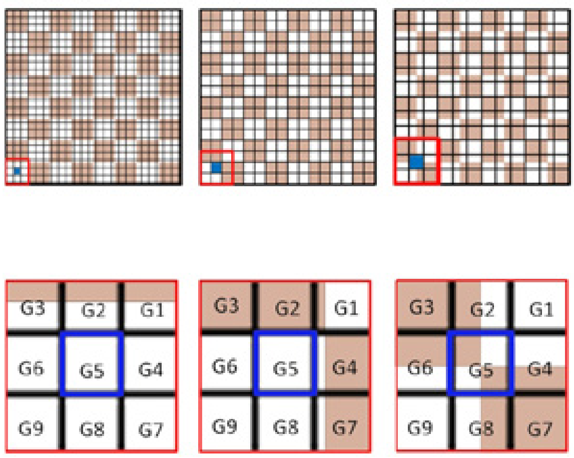

Figure 4: Unit Positions and Their Interactions with Adjacent Units in Calculation of G, P and H Values

In interpretation of IQR, knowing the values of quartiles, Q1 and Q3, has critical importance. Position of the quartiles, between 0, 00 and 1, 00, can be highly distinct, somehow close to each other or juxtaposed which at the end explains how the IQR is created in fact. When the quartiles are located distinctly far from each other, IQR gets a higher value. This also points to the deviations that exist along the entropy dataset. The deviations in the dataset point to the remarkable differences among the morphologic formations framed by the grid units, in other words among the G values, unit based built probability, of the grid units. The differences gradually affect the aforementioned P value in equation 2 above, the relational probability of 9 connected units as seen in Figure 4 above, and thus the entropy (h) value in equation 3 above.

In brief, the positions of lower and upper quartiles give information about the general morphologic character of the analysed area. Approximate Q1 and Q3 values explain that there is a recursive, proportionally continuous, built pattern in the analysed area. Analyses that are performed via grids with varying scale levels, do not necessarily effect the G values and thus the P and H values significantly in a continuous built context since the quartiles keep staying recursively approximate or juxtaposed. This kind of scrutiny, using the proposed method, helps to understand that any certain continuous and legible spatial order, no matter how it is configured, most possibly generates approximate or juxtaposed quartiles and thus a lower h-iqr value as an indicator of higher wholeness.

Correlation between the degree of wholeness embedded in the very spatial order and the feeling of wholeness revealed deep inside human being requires another research since the sense of wholeness is about complex agglomeration of manifold constituents that address intuitions. Without doubt, Alexander never ignored functional, socio-cultural and architectural content in describing spatial wholeness yet it reminds the question of whether or not his 15 properties always grant a certain level of wholeness in real space.

2.1 BEYAZIT SQUARE AND ITS EVOLUTION

Beyazit Square was, and is, one of the most historic and symbolic squares of Istanbul Peninsula, throughout the history. The square exists on the third hill of the Historic Peninsula (Freely, 2011, p. 183). The historical significance of the square dates back to Roman period and known as Forum Tauri and Forum Theodosius in Byzantium period (Ayvazoglu, 2012) (Müller-Wiener, 2002). The square exists in the very intersection of significant urban elements that make historic Istanbul image.

Beyazit Square experienced a serious demolishing interventions from the mid-20th century onwards urbanization resulting in a vast destruction of the existing built city form. Scholars (Müller-Wiener, 2002), (Eyice & Kuban, 1993), (Ayvazoglu, 2012) note that the most destructive intervention upon the square occurred in 1950's through the implementation of the Prost plan, which gave priority to the motor-vehicle traffic. The enlargement and downing of the Ordu Street in the south bound of the square resulted in not only a massive fragmentation between the street and the square, but also a remarkable change in the adjacent built environment of the square. In addition the Northwest access of the square, Vezneciler Street was also enlarged through a vast amount of massive destruction as shown in below Figure 5. Today one can still recognize the remaining parts and the fragments of the historic buildings on the site as seen in below Figure 5 street views (IMM, 2012). Today, the architectural elements that make the square's identity are foremost the Istanbul University's main gate, the Beyazid Mosque Complex, the State Library of Beyazid and the Madrasa(Ayvazoglu, 2012). Spatial assessment reports that have been developed by the Metropolitan Municipality of Istanbul (IMM, 2012) and by the Protection Board for Cultural Assets (2013) point out to the poor spatial organization of the square due to remarkable change that the square faced within the last decades.

3. RESULTS

Beyazit Square and its environs as shown in Figure 6, a 50 hectares = 500.000 m2 built area, has been selected for the comparative analysis due to the remarkable change that the square faced through the harsh urbanization over the last sixty years. Building footprints vector data (.tiff

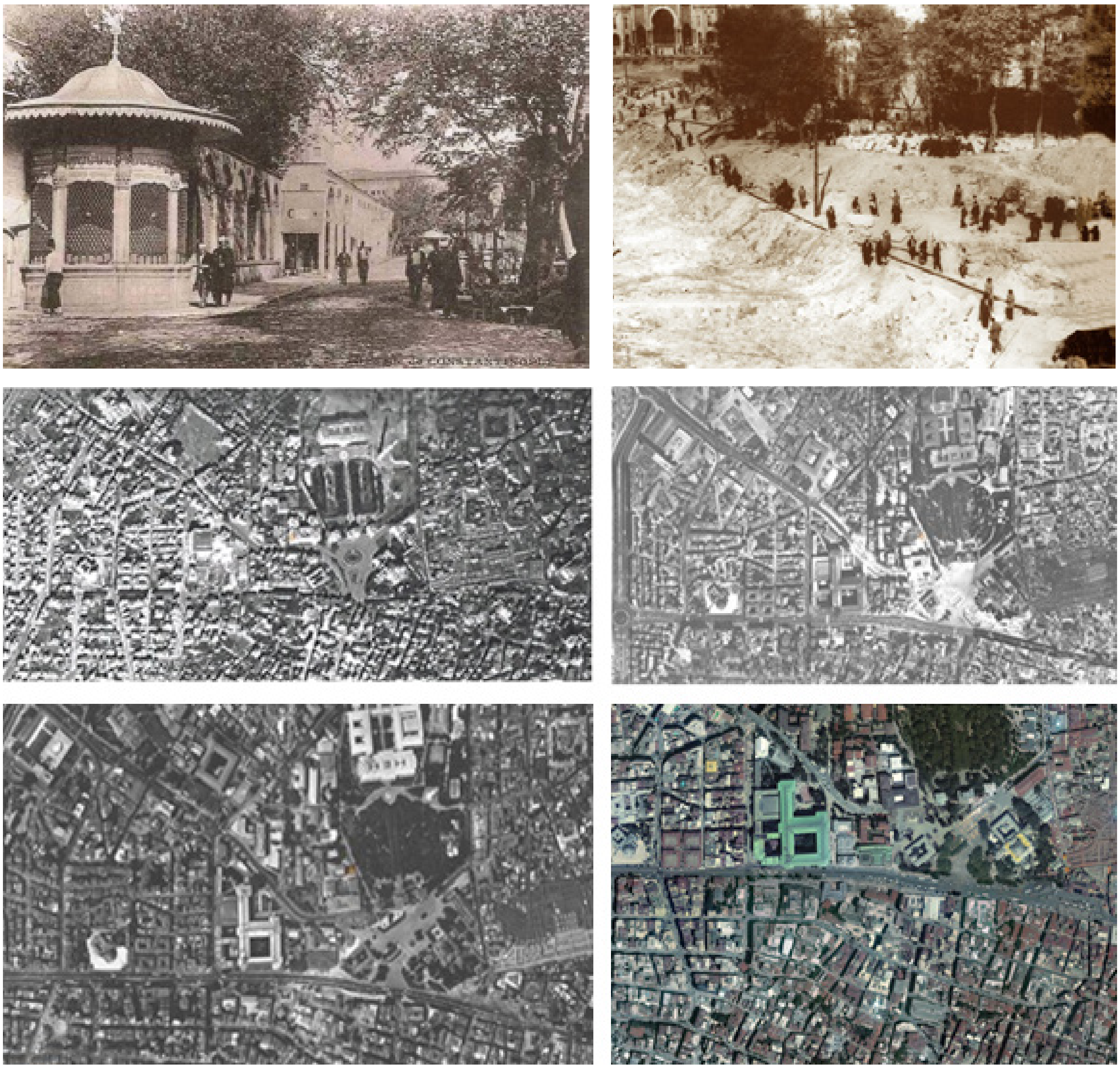

Figure 5 - Enlarged Vezneciler (Upper-Left) and Ordu (Upper-Right) Street Views. Beyazit Square Aerial Views in 1946 (Middle-Left), 1966(Middle-Right), 1982(Lower-Left) and 2013(Lower-Right) (IMM, 2012).

images 1024x1024 pixels each) belonging to two different time periods, 1946 and 2013, have been used as raw data for information retrieval. Both data sets have been analysed through 10 different grid scales as shown in Figure 7. Multi-scalar analyses, the graphs in below Figure 8, revealed that the change with the cumulative entropic state, changing degree of wholeness of the square, as seen in the below Tables 1 and 2, has deteriorated, almost halved, from 0,32bit to 0,63bit entropy level within last sixty years.

Figure 6 - 50 hectares (500.000 sqm) Beyazit Square and Environs in 1946(Left) and in 2013(Right). (1024x1024 pixels each tiff vector data)

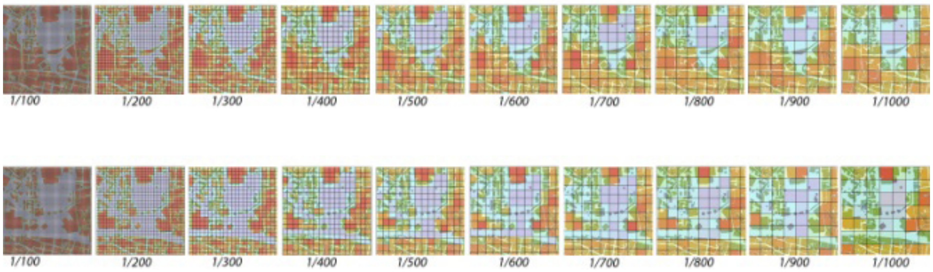

Figure 7 - Grids For Varying Scale Levels Superimposed Upon 1946 (Upper) and 2013 (Lower) Vector Data and Unit-Specific G Realizations

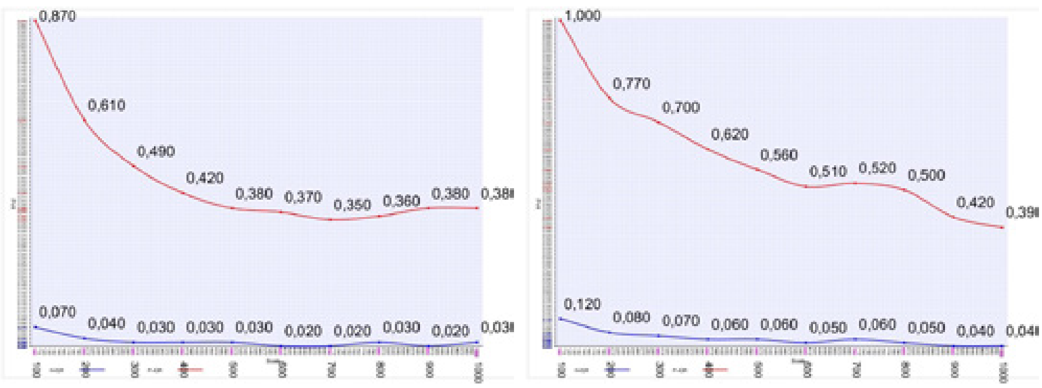

Figure 8: Multi-Scalar Analysis and G-IQR (Red Curve) and H-IQR (Blue Curve) Results for 1946(Left) and 2013 (Right) Data

As seen in Table 1 below, for 1946 data, total sum of the h-iqr values for the pixel levels that have been tested is 0,32bit.

Grid Scale (Pixel Level)	PA (Pixel Area sqmm)	Total Cell	NA Cell (exempted)	%	MA (Map Area sqm)	G-IQR	G-Q1	G-Q3	H-IQR	H-Q1	H-Q3
100	8.549	4761	272	5.7	0,006	0,87	0,130	1,000	0,07	0,050	0,120
200	34.199	1225	136	11.1	0,096	0,61	0,300	0,910	0,04	0,080	0,120
300	76.947	529	88	16.6	0,486	0,49	0,360	0,845	0,03	0,090	0,120
400	136.796	324	68	20.9	1,537	0,42	0,420	0,840	0,03	0,090	0,120
500	213.744	196	52	26.5	3,752	0,38	0,435	0,810	0,03	0,090	0,120
600	307.791	144	44	30.5	7.781	0,37	0,445	0,810	0,02	0,100	0,120
700	418.939	100	36	36.0	14.415	0,35	0,445	0,790	0,02	0,095	0,120
800	547.185	81	32	39.5	24.592	0,36	0,445	0,800	0,03	0,090	0,120
900	692.531	64	28	43.7	39.392	0,38	0,425	0,800	0,02	0,095	0,120
1000	853.268	49	24	48,9	59.800	0,38	0,400	0,780	0,03	0,090	0,120

Table 1 - G-IQR and H-IQR Values and Their Quartiles Generated for 1946 Data

As seen in Table 2 below, for 2013 data, total sum of the h-iqr values for the scales that have been tested is 0,63bit.

Grid Scale (Pixel Level)	PA (Map Area sqmm)	Total Cell	NA Cell (exempted)	%	MA (Map Area sqm)	G-IQR	G-Q1	G-Q3	H-IQR	H-Q1	H-Q3
100	8.549	4761	272	5.7	0,006	1,000	0,000	1,000	0,120	0,000	0,120
200	34.199	1225	136	11.1	0,096	0,770	0,115	0,880	0,080	0,040	0,120
300	76.947	529	88	16.6	0,486	0,700	0,150	0,845	0,070	0,050	0,120
400	136.796	324	68	20.9	1,537	0,620	0,225	0,840	0,060	0,070	0,130
500	213.744	196	52	26.5	3,752	0,560	0,240	0,800	0,060	0,070	0,130
600	307.791	144	44	30.5	7.781	0,510	0,310	0,815	0,050	0,075	0,130
700	418.939	100	36	36.0	14.415	0,520	0,280	0,800	0,060	0,070	0,130
800	547.185	81	32	39.5	24.592	0,500	0,270	0,770	0,050	0,080	0,130
900	692.531	64	28	43.7	39.392	0,420	0,360	0,780	0,040	0,085	0,130
1000	853.268	49	24	48,9	59.800	0,390	0,360	0,750	0,040	0,070	0,115

Table 2 - G-IQR and H-IQR Values and Their Quartiles Generated For 2013 Data

The change trend with the quartiles for each grid level indicates that there is a remarkable decrease with the H-Q1 for the 2013 data compared to 1946 data. G-Q1 values for 2013 data change notably slower compared to 1946. This is mostly because of the massive destructions and thus the rising amount of empty areas in 2013 built configuration. Analyses through the same grid scales generated the graphs in Figure 8 above, show the behavioural change of entropy, h-iqr values, depending on the morpho- information levels framed by various size of grid units. From smaller to larger pixel levels, 2013 spatial configuration generated relatively higher G-IQR and H-IQR values compared to 1946 configuration. In brief, a wholeness-based spatial analysis for the selected areas reveals a higher tendency for uncertainty in micro scales but lower tendency in larger scales. This outcome verifies and points out to the fact that there is always a higher potential of spatial interaction among the references of micro space towards change. As the grid scale gets larger, the number of the grid units decreases and the number of exempted units proportionally increases due to larger unit size.

3.1 MODELLING THE ENTROPIC INTERACTION

Principally entropy indicates a level of tendency towards uncertainty or disorderness. Higher entropy means higher tendency towards uncertainty. From the spatial relatedness point view, a built area framed by a grid unit is spatially and geographically related with its adjacent units and intrinsically through each other's entropic states. In other words, there is a constant interaction among the system parts. This can be visualized by an interaction modelling method.

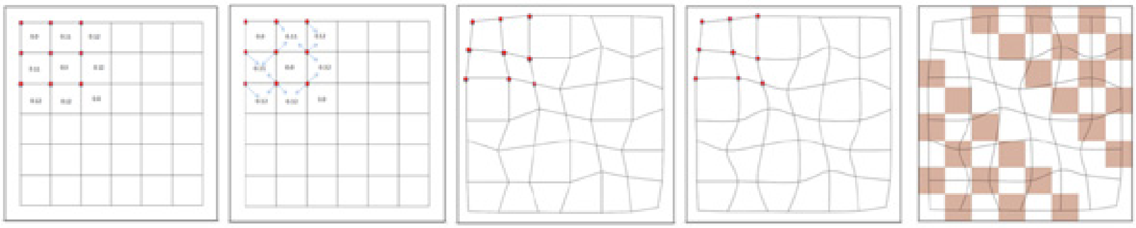

Figure 9 - Entropic Interaction throughout a Grid System (Left to Right a, b, c, d, e)

In general, each grid system highlights the vertices of each unit area that they intersect with. Mutual effect interaction, described by Brannon (2008), is here interpreted as the displacement (deformation) of the four vertices of each unit due to the forces generated by the entropy values as explained in Figure 9-a above. For each of the vertices, displacement effect is the joint force of the entropic states of the connected units as in Figure 9-b. Following the displacement of the vertices, all of them are reconnected via straight lines as seen in above 9-c visualization. Then the straight lines are converted to the curves, 9-d/e, by using Centripetal Catmull-Rom curves algorithm that is widely used in computational data modelling as an explicit piecewise polynomial representation (Yuksel, Schaefer, & Keyser, 2011).

Entopic interaction way of data visualization generates a deformed grid that allows making evidence-based comparison of how morphologic occurrences relatively interact and possibly affect each other in various built environment scenarios. Such data modelling for the 2013 case, when compared to the 1946 deformed grid in Figure 10, implies the missing structural entities are leading to a growing degree of deformed unit areas in the west, south west and south units.

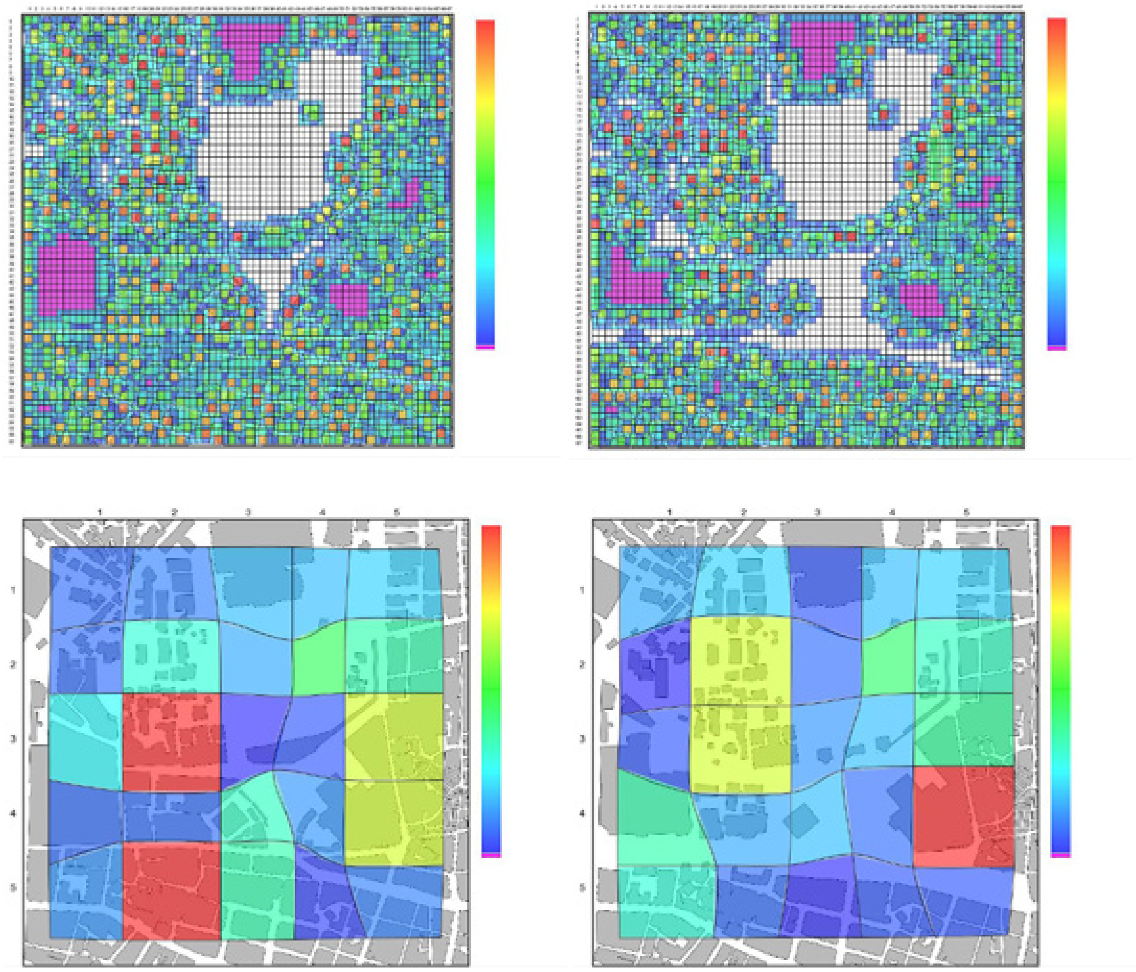

Figure 10 - 1/100(Upper) and 1/1000(Lower) Grid Scale Levels Heat Mapping Way of Entropic Interaction Modelling For 1946(Left) and 2013(Right) Built Organizations

This explains that the relative effect of entropic interaction is in a parallel trend of change in accordance with the changing state of spatial configuration. Colouring in interaction modelling exposes how the multiple effect entropic interaction deforms the grids in heat mapping way. The colour scale shows the most deformed units in red and its shades while least deformed ones in blue and its shades. Purple and white colours are used for non-deformed units. Non-deformation means that there is no entropic interaction either among the fully built units, shown in purple, or among the fully non-built units, shown in white, due to equal entropy values among the adjacent units.

4. CONCLUSIONS

Spatial evolution or change, with an increasing trend, has been studied through diverse map-comparison technics in which both traditional and advanced techniques have been incorporated for various purposes such as detecting temporal/spatial change, comparing different models or scenarios, or for calibrating/validating land use models (Visser & de Nijs, 2006). The novelty and originality that this method, morphologic measuring and visualization using Shannon's entropy, introduces is that it measures built environment through the notion of spatial relatedness which morphologically and intuitively articulates a relative degree of wholeness. Such wholeness, in addition to being context dependent, is also about the level of investigation since the system continually redefines its entropy through the changing morphologic interplay among the adjacent grid units.

This study develops an evidence-based approach for measuring spatial wholeness, e.g. completeness, and implements it on Beyazit Square, one of the major squares that has been densely influenced by the effects of automobile-led urban planning trends in Istanbul (Dokmeci et al., 2011) in the last sixty years. The success of the traditional neighbourhoods in Istanbul lies in the continuity of their growth as a whole. It is possible to feel this wholeness not only at larger scales but in micro space and its details (Dokmeci et al., 1996), (Alexander et al., 1987). The results show that the degree of wholeness of the square significantly decreased within last sixty years. This finding is also being verified in previously reported studies, the spatial assessments (IMM, 2012) , (Protection Board, 2013) that have been developed by the experts in Metropolitan Municipality of Istanbul and in Istanbul 4th Protection Board for Cultural Assets. Both reports point out the poor and fragmented spatial quality of the square noting the remarkable morphologic change that the square faced within the last sixty years. Entropic interaction way of spatial interaction modelling also deforms the grid in accordance with the morphologic change the square faced as in Figure 10 above.

Being alive, in biological terms, is a very binary matter. There are only two major degrees, dead or alive, and no other states of existence. In space, there are varying degrees of completeness or incompleteness and this study hypothesizes that it is a measurable concept beyond intuition (Alexander, 2002-2005). Karaali and Karagol (2013) define spatial incompleteness as evocative of liminal states, such as circumstances annoying the user, dissonant matches, uncertain situations, ambiguous formations and undefined regions. Adapted to spatial analysis, there are varying degrees of completeness or incompleteness in built environment and this study, using Shannon's information entropy theory, demonstrates that wholeness or completeness as spatial quality is a measurable notion. In brief, the proposed method as evidence based topologic investigation, is a promising approach to shed light on analytical assessment of morphologic possibilities and change scenarios.

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