Fractal Dimensions for Streetscape Visual Complexity Analysis

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Abstract: Streetscape visual complexity can be measured in various ways including subjective and objective methods. In this paper an attempt was undertaken to compare the subjective judgments of streetscape visual complexity with the fractal dimension calculations of the streetscapes. The commercial streetscapes around Kita Urawa Station at Saitama Prefecture, Japan were selected for the study. The perspective views of the streetscapes were displayed to a group of subjects and their judgments on the streetscape visual complexity was measured using a Likert scale. Grayscale perspective images of the same streetscapes were used for the fractal dimension calculations. Both subjective and objective experiment results demonstrated a good correlation depicting the use of fractal dimensions for streetscape visual complexity analysis is a prolific task.

Keywords: visual complexity, Subjective judgments, fractal dimension, commercial streetscapes

1. INTRODUCTION

Streetscape is a key element of townscape because of its substance that creates the city’s attractiveness and affects the pedestrians’ comfort (Ashihara, 1983). Streetscape is a combination of several profiles such as the sky, ground, buildings, vegetation, and pedestrian behaviors on the street. Therefore all these profiles are contributing to the streetscape visual complexity. Physical complexity of streetscapes could be defined and measured by analyzing physical attributes of the streetscape. However, streetscape visual complexity is a complex phenomenon and defining visual complexity is somewhat difficult task since it is basically a subjective experience. Perceiving visual complexity is different person to person based on their personal views and expectations. Thus defining and measuring visual complexity becomes difficult. Most of the time visual complexity measurements were undertaken subjectively using surveying techniques. In this paper, an attempt was carried out to compare the subjective judgments on visual complexity with an objective measurement such as fractal dimension analysis of streetscapes.

1.1 Streetscape visual complexity

Visual complexity is a direct consequence of the spatial distribution of the streetscape elements and is concerned with perception and cognition of the information. In environmental psychology, complexity is related to the involvement component, which means: “how much there is to see in a visual array?”, and to the concept of affordance that refers to what a perceived scene has to offer as far as the perceiver is concerned (Kaplan, 1988). There are lots of ways to explain visual complexity; however, there is no fixed definition for the visual complexity since it is a subjective phenomenon.
1.2 Fractal dimension analysis

Many researchers attempted to apply different kinds of objective analysis methods to measure visual complexity in cities and streetscapes. Such methods include Shannon's entropy, similarity index, space syntax method, viewshed analysis and fractal dimension analysis. In this paper an attempt was undertaken to measure the visual complexity in commercial streetscapes using fractal dimensions and to compare the results with a survey analysis using a group of subjects.

The term fractal dimension itself was brought to the fore by Benoit Mandelbrot based on his 1967 paper on self-similarity in which he discussed fractional dimensions. A fractal dimension is a ratio providing a statistical index of complexity comparing how detail in a pattern (strictly speaking, a fractal pattern) changes with the scale at which it is measured. Fractal dimensions are used to characterize a broad spectrum of objects ranging from the abstract to practical phenomena, including turbulence, river networks, urban growth, human physiology, medicine, and market trends (Wikipedia, 2014).

1.3 Past studies on visual complexity

Lynch (1960) researched the use of experiences of pedestrians to design the streetscape environments to have a pleasant experience to the travelers while travelling along the street. In his research, Lynch developed the concept of imageability; an ability for the shape, color and arrangement of elements within an urban environment to evoke a strong image for an observer.

Rapport (1990) said that the perceived number of elements within a streetscape, and particularly the "noticeable differences" between them, provides a measure of visual complexity. Further many researchers independently explained in their researches that the perceived visual complexity is very important for the pedestrians to feel the streetscape as a comfortable place to walk (Stamps III 2003, Berlyne 1974).

Hillier (1984) used space syntax method to identify the organized complexities within a city. Hillier proposes that configurations of building facades may be viewed as an arrangement of shapes which are orientated "to and away from the ground on which they stand" (Hillier 1996). He represents a building's facade as both a "metric tessellation" and as a diagram of "the dominant elements in the facade, as a pattern of convex elements" (Hillier 1996).

The viewshed or isovist analysis method was used by many scholars to measure the spatial openness within three dimensional views (Hillier 1996, Batty 2001). Using various software packages, it was easy to apply isovist or viewshed analysis to urban or streetscape analysis in a virtual environment.

Visual ambiguity, which is associated with complexity of meaning, results from the juxtaposition of the physical reality of an image and what it appears to be (Venturi 1966, Rapoport 1990). Further Rapport (1990) said the perceived number of elements within a streetscape, and particularly the noticeable differences between them, provides a measure of visual complexity.

Various scholars attempted to use fractal dimension to measure city or streetscape complexity, for example, Chen Wei (2006) has made a quantitative comparison between traditional commercial streets and modern commercial streets with the help of fractal geometry quantitative methods and entropy value calculation. Further, Wang Jianfeng (2004) has analyzed urban heterogeneity, streetscape and skyline with information entropy and spatial scale quantitative indicators which is innovative to some extent. Oku (1990) and Cooper (2003) separately studied the use of fractal dimensions to measure the geometric qualities within streetscape environments.

Thus, there are lots of past researches on streetscape and city visual complexity analysis using different kinds of methods. In this research an attempt was undertaken to analyze the visual complexity prevailing within commercial streets using fractal dimensions and to compare the results with the survey techniques.
2. METHOD

2.1 The study area

The study was conducted in the city area around the Kita Urawa station at Saitama city, Japan. Figure 01 displays the selected study area.

There are commercial and residential streets spread haphazard manner around the Kita Urawa station. Only commercial streets were selected for the study. At either side of commercial streets, various kinds of retail shops, restaurants, saloons and other commercial activities could be observed. Every commercial building has different kinds of billboards and other eye catching elements to attract pedestrians to the commercial building. All these buildings and their appearances and the advertising techniques contributed to the streetscape complexity.

2.2 Method

Twenty commercial streetscapes around Kita Urawa station were selected for the study. These streetscapes included low to high building densities. Gray scale and color perspective photographs were taken along the streetscape. Every streetscape has 6 serial vision photographs. Some of the views of the commercial streetscapes were displayed in the figure 02.
2.2.1 Subjective analysis of streetscape views

The obtained perspective views along 20 residential streetscapes were displayed to 20 subjects. The subjects were selected from the Saitama University. The subjects were asked to mark the complexity level of each streetscape in a Likert Scale after observing 6 perspective views obtained from each streetscape. Likert Scale had 5 levels.

1. Highly uniform: the commercial units and their surroundings are similar to each other. The variability along the streetscape at a minimum level
2. Uniform: the commercial units and surroundings are by and large show similar characteristics.
3. Neither complex nor uniform: the commercial units and the surrounding at the streetscape do not show a significant variability in both ends.
4. Complex: the commercial units and the surroundings show some differences in their visual characteristics.
5. Highly complex: the commercial units and the surroundings are different to each other significantly.

Based on the subjects’ view and their individual preferences, the 20 residential streetscapes were categorized into one of the levels of the Likert Scale.

2.2.2 Fractal dimension analysis

The gray scale photographs were analyzed using freely downloadable “Fractalyse” software and the fractal dimension value for each photograph was obtained. Thus each streetscape had 6 fractal dimension values for 6 perspective views. The mean of these 6 values was taken as the fractal dimension value for one streetscape. Following this procedure 20 fractal dimension values were obtained for the selected 20 commercial streetscapes.
3. RESULTS AND DISCUSSION

3.1 Fractal dimension analysis

Table 01 displays the mean of the 6 fractal dimension values of 20 streetscapes.

<table>
<thead>
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<th>Streetscape</th>
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<th>Streetscape</th>
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<tr>
<td>1</td>
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<td>11</td>
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The mean values of fractal dimensions of 6 photographs along streetscapes ranged between 1.35 and 1.98. Most of the streetscapes had values over 1.7. It implies most of the streetscapes have a high visual complexity. When an image has a high number of irregular shapes with sharp edges, the fractal dimension value becomes high. Thus, the results indicated that the selected streetscapes have a large number of sharp edges. It implies that the streetscapes have large amount of buildings and other elements with sharp edges. Figure 03 displays a view with a high fractal dimension streetscape and a view with a low fractal dimension streetscape.

![A view with high fractal dimension](image1)

![A view with low fractal dimension](image2)

Figure 03: photographs used for Fractal Dimension Analysis

3.2 Subjective analysis of the streetscapes

Perspective views of twenty residential streetscapes were displayed to twenty subjects and they were asked to rank the streetscapes based on the given Likert Scale. Afterward the Likert ranks were counted for each streetscape and the percentage of marking each streetscape under each rank in the Likert Scale was calculated. If the percentage was over 50% under a specific Likert rank, subsequently that streetscape was grouped under that category. Table 02 shows the number of streetscapes under each category in the Likert Scale.
Survey results illustrated that there were 9 streetscapes with a high complexity. Similar output was obtained through the fractal dimensions resulting 8 high complexity streetscapes with fractal dimensions higher than 1.9. These commercial streetscapes had plenty of buildings and billboards. The streets showed mixed commercial activities and the buildings and other commercial advertisements are located in very haphazard manner. As a result fractal dimensions of these streetscapes become higher. Supplementary, more than 50% of subjects ranked one streetscape as uniform. Figure 04 shows two views of the highly complex and uniform streetscapes.

4 CONCLUSIONS

The objective analysis of visual complexity on commercial streetscapes using fractal dimensions is a promising effort. The fractal dimension values ranged between 1.35 and 1.98 along with the visual density of the streetscapes the fractal dimension values changed steadily. When the building density is higher and the surrounding of the buildings displayed visual variations, that streetscape had high number of visual elements resulting high fractal dimension values. Thus the fractal dimensions could be successfully used for the visual complexity measurement on commercial streetscapes.

The commercial streets around Kita Urawa station display a haphazard development of commercial activities. The commercial activities are not properly organized; all most all streets show mixed commercial activities such as retail shops, restaurants, flower shops and convenient shops are all in the same street. Consequently the complexity of the streetscape became higher.

Because of this irregular arrangement of commercial activities, most of the streetscapes were categorized under highly complex during the survey with subjects. Accordingly both the fractal dimension results and the survey results pointed out that the commercial streets around Kita Urawa station have highly complex visual characters.
5. REFERENCES