Study on Landscape Recognition that Uses Image Processing Technology by Local Inhabitants in Kamakura

Satoshi Yamada*,1, Nobutaka Shintani2 and Hirotomo Ohuchi3

1Assistant Professor, Dr. Eng., Department of Architecture and Urban Design, College of Science and Engineering, Ritsumeikan University, Japan
2Graduate Student, Graduate School of Industrial Technology, Nihon University, Japan
3Professor, Dr. Eng., Department of Architecture College of Industrial Technology, Nihon University, Japan

Abstract
This paper studies landscape recognition of the Kamakura historical area by inhabitants. A region is composed of sets of individual events with a broad range of scales. Such embodiments constitute the regional environment that is made up of both nature and man-made structures. In a regional environment, the sharing of these mental spaces is considered to be a necessary precondition for regional coexistence. This study focused on landscape recognition as a shared mental space. A cognitive region map is drawn using the results of a questionnaire, and this map reveals the inhabitants' recognition of the landscape. A visualization model was used to analyze the area's environment and the relationships with the inhabitants' recognition of the landscape. This paper quantifies the urban forms of the regional environment using fractal dimensional analyses of aerial photographs and considers their relationships to the inhabitant's cognizance of the landscape. Therefore, the objective area of the fractal analysis is extended to include the region of "a landscape, which has the identity of Kamakura," and "a place that has changed (recognition)," In this paper, the above analysis was used to quantify complex urban forms. The paper evaluates landscape recognition and the relationships of the urban forms in terms of the continuity of the fractal dimensions.

Keywords: landscape recognition; fractal; visualization model; local inhabitants; historical city

1. Introduction
Regions are made up of groups of individuals of various scale. In all scales, the individual is a part of the whole, and the process by which these parts form a whole is a series of interactions. Individual variations are produced at the stage at which this continuity becomes a whole, however, the whole is affected at each stage. The aggregate that has an effect at a certain stage affects the individuals, without them being aware of it, eventually affecting the whole this process results in the formation of a whole by individuals. Such embodiments constitute the regional environment that is made up of both nature and man-made structures. Buildings with various uses and blocks and city centers and so on that are aggregates of these buildings can be thought of as manifestations of social systems and regional culture. People live in these man-made structures and, as they do not exist as isolated individuals, they create various images as mental spaces. The sharing of these mental spaces is considered to be a necessary precondition for regional coexistence, which has recently become an important issue in planning. This is the shared recognition of the embodied region as a common asset. Permanent residence and the possession of a regional awareness lead to the sustainability of the region.

This study focused on landscape recognition as a shared mental space. Landscape recognition is the process of recognizing the region that is formed in the course of daily life. Landscapes are considered to be the mental spaces (cognitive regions) created from
various images with respect to interrelated spaces. It is essential to discover the relationship between the local environment (morphological characteristics) — made up of nature and human creations formed in the process of regional coexistence — and the process of human perception.

Fractal dimensional analysis is a method of quantitatively analyzing the complex forms made up of natural shapes and human creations. Analysis techniques that use fractal dimensions are able to quantitatively show the complexity of events and shapes that at first glance appear to be irregular. This is done by quantifying the relationship between the self-similar parts and the whole.

Using this technique, the objective of this study was to consider the relationship between (1) landscape recognition formed by the aggregation of the mental spaces of individuals and (2) the fractal dimensions for the physical environment of the region, quantified from the relationship between the parts and the whole. This study places particular focus on regions in which the domain of landscape recognition has been opened in previous studies. The relationship between urban forms and landscape recognition will be considered from the continuity of fractal dimensions.

2. Explicate from Previous Study

1) Kurebayashi (2004) drew a cognitive region map using the results of the questionnaire given to Kamakura inhabitants. The questionnaire was based on the sphere graphic method, and the cognitive region map determined the extent of landscape cognition and the component elements.

2) Yamada (2005a) then made a landscape image map. The cognitive region map was overlaid with the visualized model developed by Negoro (2004).

3) The extent of landscape recognition from the person’s visualization of the area and the relationship to the spatial component of the area can be evaluated.

4) Yamada (2006) focused on cognition of "a landscape, which has the identity of Kamakura," and "a place that has changed (recognition), "A model of landscape recognition is then developed from the spatial component of the area.

In this paper, the relationship between the characteristics of landscape recognition and the urban form are evaluated by means of a fractal analysis method.

5) Chonabayashi (2005) constructed a method of quantifying morphological attributes with fractal analysis by using image processing technology.

6) Kuroiwa (2004) applied a typification technique to the urban area.

This study analyzes previous studies 1) and 2) in terms of the breadth and constituent elements of landscape recognition. Moreover, the visualization model in 3) is used to consider the relationship between visualization and landscape recognition in 4).

The novelty of this study as compared to previous studies and other related papers regarding landscape recognition lies in the use of fractal analysis 5) and 6) to consider the relationship between landscape recognition and urban forms. In this paper, the structure of landscape recognition is considered from the unique perspective of visibility and self-similarity of urban forms through the use of image processing.

3. Area of Study (Fig.1.)

The area subject to the investigation was Kamakura City in Kanagawa Prefecture, Japan. This is a historical city with a rich cultural heritage. Blessed by nature, the city has mountains on three sides and the sea on the fourth side. An historic road, Wakamiya Ooji, runs from the mountains to the sea through the city center. The city is 70km from Tokyo, and in the summer is crowded with tourists. Urbanization, however, has negatively affected the environment. Recognition of the landscape by the inhabitants is, therefore, an important aspect of city planning and design.

4. Study Method

The research process is shown below:

1. Preparation of the recognition area through a questionnaire survey using the cognitive region map method.
   Environmental recognition and area and component landscape recognition are analyzed to understand its
characteristics.

2. Creation of three-dimensional visualization models and landscape image map (Chapter 7 Ref.10, 11).

A topographical model will be created from GIS data, and from a simulation conducted using the human visible spectrum as a light source. A landscape image map will be created by superimposing this visualization and the cognitive region map.

3. Fractal analysis of urban forms (Chapter 8)

Using fractal dimension analysis an analysis of the continuity of fractal dimensions for urban forms will be conducted. With regard to the problem of shadows in aerial photographs, a three-dimensional model will be prepared and an analysis of fractal dimensions for the same models in spring, summer, fall and winter will be conducted. Yamada (2007b) has confirmed that differences in shadows due to variations in time do not affect the continuity of fractal dimensions.

5. Investigation Outline (Table 1. and Table 2. Fig.2.)

Sphere graphic method

Subjects: In order that the subjects of the investigation target might clarify the environmental recognition of the general public, questionnaires were given to local inhabitants who were older than a third-year junior high school student.

Design of questionnaire: The investigation focused on the territory recognized physically or mentally by the subject. An examiner presented the questionnaire containing a blank space. The subject was asked to fill in the answers to the questions and draw a representation of the landscape at a scale of 1/10000. The valid responses received were 103.

Items of the questionnaire*3

1) Attributes.
2) Cognitive regions of Town, Sea, and Mountain.
3) Cognitive region Component Element.
4) Landmarks.
5) Districts.
6) Use of space in daily activities.
7) Transportation.
8) A landscape, which has the identity of Kamakura and where it has changed.
9) Component element of the landscape, which has the identity of Kamakura and the place where it had changed.

Points 1) through 5) are the main points used to draw a cognitive region map. Points 8) and 9) comprise the analysis of landscape recognition, and points 6) and 7) are used for supplement.

The questionnaire cognitive regions, components, and reasons for the form and layout region were analyzed, and a cognitive region map drawn. A cognitive degree*4 of region for each cognitive region and the cognitive degree of the component (point, line, surface, and change in time) are then calculated (Lynch 1960). Fig.3. is a cognitive region map in Kamakura. Table 3. lists the component elements.

6. Cognitive Region Map (Fig.3., Table 3.)

The cognitive region map is used to rearrange the descriptions below regarding environmental recognition in the object area.

The city spreads out from the station and its borders approximate the geographical features. The cognitive region of the mountain spreads out to the west side and cognitive degree of Mt. Genji is high. The cognitive region of the water is concentrated in the area of the bay, and while the cognitive degree of the Nameri River is high, it does not influence the region’s composition. The cognitive area of Kamakura City is formed by highly recognized surface elements, shows a tendency towards duplicating the cognitive region and is recognized as "bustle". Various temporal elements*5 are formed and influence the formation of...
the recognition area.

The environmental recognition of the inhabitants of Kamakura City can be understood from the cognitive region map.

7. Relationship of Visualization and Landscape Recognition

A landscape image map reveals landscape recognition from the relationship of visualization and landscape recognition. This map was used to examine landscape recognition among the area's inhabitants. The landscape image map was made using the visualization model (developed by Negoro (2004)) created from the results of the investigation, cognitive region map and previous research. It assigned 2 points to the cognitive region obtained from the cognitive region map. The points of the visualization model are Wakamiya Ooji around Kamakura Station (point 1) and Yuiga beach (point 2); these points are the center of the region perceived as "bustle".

In the case of Kamakura City, the overlapping region of the two existing points are associated with "bustle" and this is important in terms of recognition by the local inhabitants as it is an effective base for landscape recognition. The landscape image map can be analyzed to determine the relationship between the visualized area, the component elements, the various cognitive regions of the landscape, and environment recognition.

7.1 A place that has changed (recognition)

This cognitive region spreads out along the coastline, and Wakamiya Ooji. The cognitive region spreads out primarily due to the high level of the town and water components. These are superior to the "bustle" component and are distributed mainly in the urban district. Eleven of the top twelve items are inside the acknowledgment territory. As for the lower item, it is outside the cognitive region and the invisibility area. (Fig.4., Table 4.)

7.2 A landscape which has the identity of Kamakura

This cognitive region spreads out along the coastline, and Wakamiya Ooji, and includes Tsuruoka Hachiman shrine. The cognitive region spreads out based primarily on the high level of the town, water and mountain components. The primary anchor points are both within the visibility areas of the two visualization models. When plotted as a component on the map, most are distributed near the boundary of invisibility inside the visible region. (Fig.4., Table 4.)

The visualization model is used to evaluate the relationship between the visibility of the regional space and landscape recognition.

8. Fractal Analysis

8.1 Selecting the range of the analysis

Fractal analysis of aerial photographs (1 pixel = 60 cm) was conducted as an analysis of urban forms. As the particular focus of this paper is a consideration of the relationship between landscape recognition and urban forms, an analysis was conducted of the range of two types of domain obtained from the landscape image map: "a place that has changed (recognition)" and "A landscape, which has the identity of Kamakura".

- Analysis Area 1 (Tsuruoka Hachiman shrine area): the area from the Tsuruoka Hachiman shrine at the center of the domain with a recognition strength of 60% for "A landscape, which has the identity of Kamakura" to the domains that range from 80% to
60%.

- Analysis Area 2 (Mt. Genji area): the area from Mt. Genji at the center of the domain with a recognition strength of 20% for "A landscape, which has the identity of Kamakura."

- Analysis Area 3 (Zaimokuza 3-chome area) and Analysis Area 4 (Yuigahama 1-chome area): The area with a recognition strength of 20% for "a place that has changed (recognition)."

- Analysis Area 5 (Zaimokuza area) and Analysis Area 6 (Yuiga Beach area): The area formed with the line connecting the bridge contacting the Nameri River and the ocean and the endpoint of the coastline as the median. Analysis Area 5 covers the domain extending toward the Zaimokuza from the point at which the Nameri River contacts the ocean, with a recognition strength of 20% for "A landscape, which has the identity of Kamakura" and a recognition strength of 40% for "a place that has changed (recognition)." Analysis Area 6 covers the domain extending toward Yuiga Beach, with a recognition strength from 60% to 40% for both "A landscape, which has the identity of Kamakura" and "a place that has changed (recognition)."

- Analysis Area 7 (northeast Wakamiya Ouji area) and Analysis Area 8 (northwest Wakamiya Ouji area): the area covering the northeast and northwest sections bounded by the historic road Wakamiya Ouji. Analysis Area 8 is the area covering the domain extending on the northwest side of Wakamiya Ouji, with a recognition strength of 80% to 60% for "a place that has changed (recognition)." Analysis Area 7 is the area covering the domain of "A landscape, which has the identity of Kamakura" with the same length and width as Range 8 but extending to the northeast.

- Analysis Area 9 (Wakamiya Ouji north area): the area covering the domain for "A landscape, which has the identity of Kamakura" extending along Wakamiya Ouji that includes the bustling area around Kamakura Station, up to the area at which the Yokosuka train line intersects Wakamiya Ouji with a recognition strength of 80% to 40% for "a place that has changed (recognition)."

- Analysis Area 10 (Komachi street): the area covering the domain extending along Komachi-street with a recognition strength of 80% for "a place that has changed (recognition)."

- Analysis Area 11 (Wakamiya Ouji south area): the range covering the domain of "A landscape, which has the identity of Kamakura" that extends south from Analysis Area 9, up to the intersection between Wakamiya Ouji and Shonan road.

Gray scale images of the aforementioned Analysis Areas with the long side measuring 1024 pixels were prepared and, following Binary process*, fractal dimension analysis was conducted (Fig.5.).

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*Binary process: A method for converting grayscale images into binary images. It involves thresholding the grayscale values to classify pixels as either foreground or background. This process is often used to simplify images for further analysis, such as calculating fractal dimensions.
8.2 Box-counting analysis (Fig.6.)
When a binary image is covered by squares with each side measuring \((r)\) pixels, if the number of squares contained in the target number of pixels is \((N)\) for each pixel interval \((r)\), the following equation is obtained:

\[
N(r)\cdot r^{-D} = C
\]

where \(C\) is a constant and \(D\) is the fractal dimension.
If equation (1) is transformed, the following is obtained:

\[
\log N(r) = \log C - D \log r
\]

Here fractal dimension \(D\) indicates the slope of the \(\log r\) and \(\log N(r)\) line and can be estimated using the least-squares method. When the regression line that is obtained shows good linearity (in other words, when the value of the decision coefficient \(R^2\) is high), the image being analyzed can be confirmed to possess a fractal nature.

8.3 Consideration on the threshold
As a study of the threshold value for binarization, fractal analysis was conducted using threshold values from 1 to 255. The fractal dimension tendency of the threshold value in each Analysis Area was clear, and the decision coefficient was within the range of the fractal analysis methods established in previous studies. Fractal analysis determined that, at a threshold of 125, the fractal dimensionality was 1.8693 to 1.5549 and the decision coefficient was 0.9996 to 0.99409 (Table 5.).

8.4 Classification by fractal dimension continuity (Table 6. Fig.7. and Fig.8.)
Cluster analysis was conducted in order to examine the trend in the continuity from the detailed view to the broader view of the fractal dimension.

The fractal dimension (fractal section value) of each box size was measured using the box-counting method, and cluster analysis was conducted using the changes in these values.

First, let us examine the analysis sections. As Fig.7. shows, all of the fractal section values are high in the sections in which the number of pixels on one side is 32 to 64, and the characteristic trends are lost. Accordingly, in cluster analysis, fractal section values of 1024 to 64 pixels were used.

Cluster analysis (using the furthest neighbor method) was conducted based on the Euclidian distance between target ranges, as derived from the change in fractal section values. Fig.9. shows a tree diagram. The morphological attributes were as follows.

Analysis Area 1, 2, 3, 4 and 6 showed a continuous decrease, with the fractal section values decreasing at a constant rate from detailed to broad areas (minimum decrease -0.0267 and maximum decrease -0.1946).

In Analysis Area 5, 8 and 10, there was little decrease in fractal section values from detailed to broad areas (average decrease -0.0707), and the value increased in broad areas. The change in section value...
In Analysis Area 7, 9 and 11, the fractal section value in detailed areas was low (mean value 1.7339). In broad areas, however, the value increased (average increase 0.161667).

9. Conclusion

In this study, the landscape recognitions of residents of the traditional city of Kamakura were examined using recognition domain drawings, landscape image maps, and fractal analysis. The results of the analysis were as follows.

"A landscape, which has the identity of Kamakura"

In Analysis Area 1, 2 and 6 with "A landscape, which has the identity of Kamakura" domains, similar fractal dimension continuities were obtained. The fractal section values decreased continuously from detailed to broad areas. In Analysis Area 1 and 6, in which the recognition strength was particularly high, the fractal dimension continuity trends were similar despite the different environments (mountain and ocean).

The recognitions of the residents on the ocean side were formed with the Yuigahama Coast, a location that affords a scenic view, as a central component within the visible domain that possessed the morphological attributes noted above.

The residents on the mountain side tended to recognize as "A landscape, which has the identity of Kamakura" the components made up of structures and the entrances to valleys, such as Zeniarai sarasvati and the Kenchou temple located at the boundary between the visible and non-visible domains. Within the area possessing the aforementioned morphological attributes, valley entrances and historical structures such as temples or shrines at the edge of the visible domain were recognized as complex elements.

"A place that has changed (recognition)"

Wakamiya Ouji and the Tsuruoka Hachiman shrine and other centrally located components are located within the cognitive domain, and 9 of the top 12 items are distributed in the urban zone. The lower-ranking items such as Hase Street and Enoshima are located in the non-visible domain or outside the cognitive domain. Moreover, the cognitive domain tends to extend to Kamakura Station and Komachi Street and to introspection type spaces.

Relationship between "A landscape, which has the identity of Kamakura" and "a place that has changed (recognition)".

1) The areas in which "a place that has changed (recognition)" was strong (Analysis Area 5, 8 and 10) showed similar fractal dimension continuity. There was not much of a reduction in fractal section values from detailed to broad areas, and the value increased in broad areas.

2) The areas in which "A landscape, which has the identity of Kamakura" were strong (Analysis Area 7, 9 and 11) also showed a similar fractal dimension continuity. The fractal section values were low in detailed areas but increased in broad areas.

The cognitive domains for "A landscape, which has the identity of Kamakura" were centered on Wakamiya Ouji and the Tsuruoka Hachiman shrine and extended to the area around Kamakura Station and the area around Yuiga Beach. These tended to include domains of "a place that has changed (recognition)."

In both of these regions, residents tended to identify common components possessing a high cognitive degree. However, their recognition of "A landscape, which has the identity of Kamakura" was based on visibility. These domains were dispersed in areas that had morphological attributes like those in 2). In contrast, the places recognized as "a place that has changed (recognition)" were integrated domains, comprising primarily bustling places and other daily life environments that also included non-visible domains, located in areas that had morphological attributes like those in 1).

Through the use of image processing, this study was able to determine the relationship of landscape recognition to the visibility of spatial components and the complexity of urban patterns.

Acknowledgment

This study was funded by Grant-in-Aid for Scientific Research (C) No17560561 and Expense Subsidies for Private University Special expenses for graduate school "Construction of the design technique which uses complicate theory at Architecture, city and regional planning".
Notes
*1. Fractal dimension: There are many different definitions for "dimension" in the field of mathematics. Typical dimensions include the similarity dimension, the measurement dimension, the covering dimension and the capacity (or "box-counting") dimension. All of these are related to the fractal dimensions first defined by B. Mandelbrot. The covering dimension is determined by the relationship between the similarity dimension and the measurement dimension, while the capacity dimension is an expansion of the measurement dimension and the covering dimension\[^{22}\]. The similarity dimension, measurement dimension and covering dimension are effective for similar shapes created through clear repetition, while the capacity dimension is effective for irregular shapes that actually exist in the natural world.

*2. Sphere Graphic method: This method is effective when focused on a subject who has adequate recognition of the area. It is suitable for studying relatively limited spaces in small areas, such as the area surrounding a personal dwelling. The subject's cognitive area is obtained by indirectly exploring the structure through a spread, a spatial break, etc.

*3. Items of the questionnaire.
1) Attributes: Age, sex, occupation, years of inhabitants, and location of dwelling.
2) Cognitive regions of Town, Sea, and Mountain: Subjects were asked to circle areas on a map that represented their images of Town, Sea, and Mountain.
3) Cognitive region Component Element: For each of the above 3 regions, the subjects were asked, "While remembering what, you surrounded?" and the elements that composed each cognitive region was investigated.
4) Landmarks: The subjects were asked to draw a map as many details or impressive things as they could remember about Town. Objects other than buildings were also acceptable (places, events, trees, signboards, etc.);
5) Districts: Subjects were asked to enclose on a map any areas they associated with activity.
6) Use of space in daily activities: Investigation of places where a fundamental life activity (daily life activities and 4 sporting activities) takes place.
7) Transportation: Subjects were asked to draw a map of their daily movements, including routes they used often and routes they sometimes used.
8) A landscape, which has identity of Kamakura and where it had changed: The top of the map in the questionnaire encloses a territory that is checked against "a good landscape, which has identity of Kamakura" and "a place that has changed." When the change is diachronic, the territory shows that, too.
9) Component element of the landscape, which has identity of Kamakura and the place where it had changed. This is revealed in both "Kamakura and the place where it had changed." When the change is diachronic, the territory shows that, too.
10) Component element of the landscape, which has identity of to Kamakura" and "a place that has changed," When the change is diachronic, the territory shows that, too.

*4. Cognitive degree: The ratio of the sum of the locations recognized by the individuals (sample) in a certain area to the total number of respondents in that area. This value indicates the ease of recognition at that location. [Cognitive degree = (Number of cognition items / Number of respondents) x 100].

*5. Temporal elements: Issues in planning theory regarding the concept of space have come to include not only physical and visual elements but also time series processes that fluctuate temporally. Accordingly, components that cannot be determined through physical and visual point, line and plane classification are classified generally as elements that vary over time.

*6. Binary process: Binarization is the process of obtaining of binary images from grayscale images, color images and other multilevel images. Specifically, for a grayscale image \( f(x,y) \) and a threshold value of \( t \), binarization is the process of making the \( f(x,y) = f(x,y) \text{ if } f(x,y) \geq t \) values equal to 1. \( f(x,y) < t \) values equal to 0.

*7. Cluster analysis: After a variety of methods had been considered (including the nearest neighbor method, furthest neighbor method, centroid method and Ward's method), the furthest neighbor method that enables classification in the most straightforward manner was used for this study.

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A part of the present study was reported in the following research.

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