Affective Engineering for Mud Wall Texture using Self-organizing Maps

Toshio TSUCHIYA

Shimonoseki City University, Japan, tsuchiya@shimonoseki-cu.ac.jp

Abstract: Affective/Kansei engineering is used to analyze subjective responses to a streetscape plan for a historic townscape. The Chofu area in Shimonoseki was chosen for the research. The appearance of the streetscape is evaluated based on actual photographs using a traditional semantic differential method. Guidelines are often formulated to promote landscaping plans in historic towns; it is especially important to formulate color guidelines so as to unify the colors in an area undergoing change. The guidelines must be formulated according to regional requirements since color planning is strongly influenced by the local identity or brand. The affective engineering proposed in this study reveals representative design elements arising from the regional characteristics of the area and its people. The Chofu area is famous for its streetscapes of mud walls. The pilot investigation using a self-organizing map validated the evaluation of mud wall colors.

Keywords: Affective engineering, SOM, Mud wall, Texture

1. INTRODUCTION

This study illustrates affective data analysis for a historic streetscape. Chofu in Shimonoseki has a historic streetscape that is famous for its beautiful earthen walls. This study examines Chofu's street views with the intention of preserving and conserving such streetscapes. The experimental results are transformed into guidelines for unifying colors. Within the field of affective/Kansei engineering, computing the semantic space has been an important research issue since it was pioneered by Nagamachi at Hiroshima University (Nagamachi, 1995). Affective engineering aims to measure customers' subjective responses to products and to identify the properties from the responses using mathematical models.

This study aims to use self-organizing maps (SOMs) to analyze mud wall colors (Kohonen, 2001).

SOMs have been used to reduce multidimensional variables into a small number of axes. SOM performance has been confirmed in a previous study on affective engineering (Shiraki, W., et al., 2003). Our interest in affective engineering methodology is to compute the position of attributes in a semantic space. This paper illustrates a two-tiered approach for the analysis of mud wall colors. First, a color measurement is used to observe the unity of the color distribution of the walls. The distribution is translated into color guidelines based on the Munsell color system. Next, streetscape samples characterized by a color histogram of the photo image are mapped onto a semantic map computed by the SOM. The map is used to examine the relationship between the textured wall images and the affective meanings. The mapping is used for the maintenance and further improvement of mud wall textures.

2. EXPERIMENT ON MUD WALL COLORS

2.1. A.Target Area for the Experiment

Chofu is a well-known tourist area (Tsuchiya, 2006). It is popular because of its historic streetscape, which includes mud walls built using the distinctive, traditional Japanese construction method. The Chofu mud walls consist of clay mixed with rapeseed oil, giving the red-tinged color that creates the distinctive appearance as time goes by (Figure 1). However, only a small number of walls built in old times still remain. The city office has maintained the old walls, and at the same time, promoted the construction of new mud walls forming a desirable streetscape appropriate to Chofu through a subsidy system. This public support for private landowners started in 1996 and has resulted in Chofu currently being able to show its historic streetscapes. The subsidy system was terminated in 2010, because it had mostly achieved its objective of streetscape planning. Therefore, a system for maintaining the developed streetscape does not currently exist. To retain the constructed streetscape, guidelines for building new walls or repairing existing ones, which will typically impose restrictions on landowners, are required to establish a common understanding. Inspired by circumstances in the city office, this project was initiated to formulate guidelines to maintain the mud wall streetscape. The assigned task of this study was to collect basic data for guidelines in the area (Tsuchiya, 2009), (Tsuchiya, 2013). Unifying the colors of mud walls is especially important to retain Chofu's atmosphere. This paper discusses the investigation of color measurement and an affective examination of mud wall surface texture. The results of these two experiments are formulated into guidelines for streetscape planning.

Figure 1: A mud wall in historic Chofu.

2.2. Distribution of Mud Wall Color

The mud wall colors were measured by display colorimetry to investigate the color distribution in the Chofu area. The data used in this experiment were 90 photographs taken on the streets of Chofu with a compact digital camera. The photo locations were almost uniformly selected using the results of cumulative inspections, which included the historic earthen-walled streets. All the photographs were taken under the same conditions, including the height of the viewpoint. Shooting started at 10 a.m. and continued until 2 p.m. on a day with unchanging weather. The pictures were saved as 2,048 × 1,536 pixel jpeg images (Figure 1). The color of each wall was measured by the "Area Colorimetry System Landscape version by GISS", which includes a color correction algorithm. Figure 2 depicts a CIE 1931 xy chromaticity diagram with the distribution of the 90 mud wall colors indicated by the red markers. The markers are distributed from the center area, corresponding to a white or gray color, to the right middle area, which represents a yellowish red color. The color of the mud walls in Chofu is currently unified as an achromatic or red-tinged color since the 90 markers show a narrow distribution along the white or red-tinged area. This means that the mud walls in Chofu are either white, which is generally the color seen on historic Japanese streets, or tinged with red, which is the characteristic color of Chofu. Therefore, color planning for mud walls in this area is reasonable to focus on maintaining the current color unity. Figure 3 shows the color-projected guidelines using the hue and chroma axes of the Munsell color system (value = 6) for builders of mud walls based on the color distribution. The streetscape can be maintained if landowners in the target areas agree to the projected guidelines.

3. AFFECTIVE EXPERIMENT ON MUD WALL SURFACES

3.1. Affective Experiment on Mud Wall Images

For future streetscape preservation and improvement, it is important to examine the affective influences of the mud walls on the Chofu streetscape. In this study we undertook a streetscape evaluation experiment to obtain visual evaluation data of mud wall designs. We then analyzed the relationship between the obtained affective evaluation and the mud wall designs. The results of the analysis will be used in assessing existing mud walls and constructing new walls.

The aim of the affective experiment was to reveal the relationship between the mud walls and

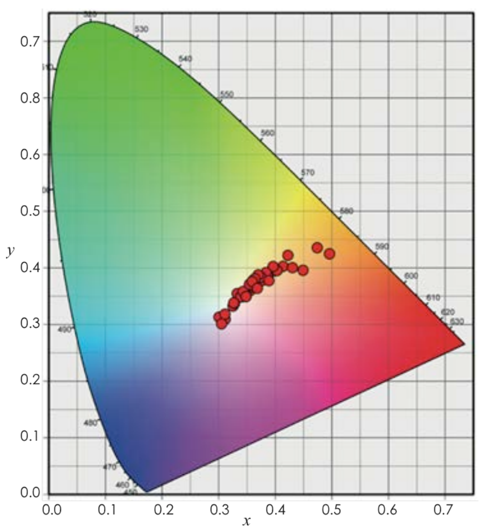


Figure 2: Color distribution of the Chofu mud walls(*CIE 1931 xy chromaticity diagram*).

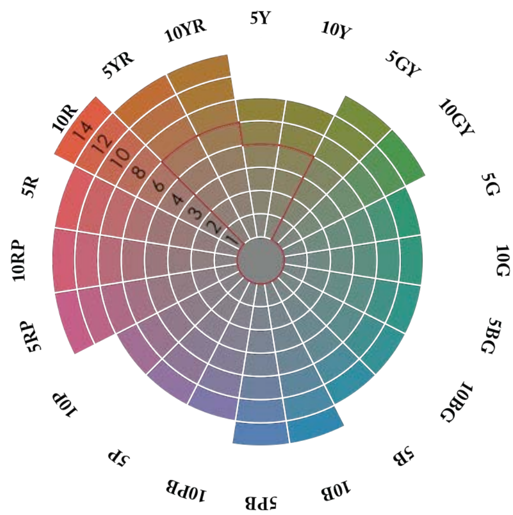


Figure 3: Color guidelines for mud wall builders based on the color distribution.

human sentiment. A general semantic differential questionnaire was prepared for 20 individuals (13 males and 7 females). The stimulus for this experiment was the 90 photographs (2,048 × 1,536 pixels) used in the previous experiment. In the experiment, the photo samples were projected onto a screen and evaluated on a five-point semantic differential (SD) scale using 15 pairs of adjectives (Table 1). The adjectives used as evaluation words were gathered from a previous study (Nakama & Kinoshita, 2010) and from experts in design and regional development. The data obtained from the questionnaire responses by the 20 subjects were averaged, resulting in a 90 by 15-element data matrix.

3.2. Color Histogram of Mud Wall Surface Images

The surface image of the mud wall is essentially treated as a texture. It would appear that an affective feeling is created by the surface texture of the mud wall. It is therefore reasonable to examine the affective relationship between the human sentiment and mud wall images. However, there is really no major difference between the grain patterns of the mud walls constructed using a similar architectural method. The most important element of the affective representation is the color shade created by the material varying over time. Therefore, we employed a color histogram representation to define future measurement of the mud wall design. The histogram depicts the number of the dot for each color value. The input images were 90 digital photographs, that is, 300 × 300 = 90,000 dot full color jpeg images, representing different characteristics of the color shade, clipped from the sample jpeg files used in our earlier affective experiment. The color of each dot, as specified in the digital image, was represented using the Hue, Saturation, Value (HSV) model. The numbers of bins for hue, saturation, and value were 20, 5, and 5, respectively. Frequencies were computed as a three-dimensional histogram of HSV, resulting in a total number of bins of 20 × 5 × 5 = 500. The computed frequency was normalized, since the maximum value is 100. Then, four samples representing different colors, as measured by the display colorimetry, were selected as criteria (Figure 4). D27 was selected as the average color of the sample, while D25, D50, and D76 were selected as distinctive colors. The Bhattacharyya distance was used to measure the difference between the histogram for each criterion and the other 89 samples. The four computed distances for each histogram were employed as future values of the texture. Figure 5 shows the computed distances for the 90 samples with respect to the criteria of samples 76 and 25. The distances were normalized to [0,1]. Then, the 15-elements of the normalized affective evaluation and the four distances were used in the affective analysis of the mud wall design.

4. AFFECTIVE ANALYSIS USING SELF-ORGANIZING MAPS

4.1. Semantic Maps using SOMs

The data gathered from the affective experience and the texture representation were analyzed using a SOM, which can visualize multidimensional data into a sheet-like neural-network array [2].

Table 1: Affective words used in the experiment

realistic - fantastic	modern - classic	wilderness - tidy
noisy - quiet	ugly - beautiful	tasteless - tasteful
artificial - natural	dark - bright	indistinctive - distinctive
uneasy - easy	not high-grade - high-grade	cold - warm
senseless - smart	unfriendly - friendly	atypical Chofu - typical Chofu

The units translate various input signals into certain reduced coefficients. The SOM aims to acquire features of the input data to classify unknown or unlearned data into the correct classes. A basic SOM network is composed of an input layer and an output layer. An output unit has the same dimensions as an element within the input vector or the input layer. A unit in the input layer corresponds to an element, or a variable, of the input vector, which means an evaluation word or a design future in the case of this affective analysis. Therefore, a one-to-one relationship exists between an input unit and an element of the input data. Additionally, the links from each input layer are connected to all output units by an arrow. Thus, the number of elements in the output unit is the same as the size of the input vector or the array of the input unit. The iterative learning process relies on competitive and cooperative learning, which is unsupervised (self-organized) and therefore, no teacher is required to search for appropriate weights for the output units.

4.2. SOM Learning of Mud Walls

The next step involved learning an SOM map from the 90 sample pictures using the SD data gathered in the experiment. Figure 6 shows the resulting SOM map on a 20 × 18 grid (map unit size u = 360). The input data were obtained from the 90 samples (images) of the 19-dimensional normalized vectors (variables). A vector of the sample was used as the input vector for SOM learning. Each learning step was completed by recomputing the output unit vectors, for each iteration of 90 samples. The network structure was a hexagonal topology, which is the most usual form for SOM construction. The number of learning steps was 15,000. The initial learning rate and neighborhood radius were 0.2 and 10, and these were changed to 0.1 and 5, respectively, in the final 10,000 steps. In Figure 6, a hexagon overwritten with a dot or sample number (such as "D1," which means the nearest unit to sample texture 1) indicates a unit in the output layer. Other hexagons represent the distances of the output unit vector between pairs of neighboring units. The distances between units on the map correspond to the degree of the relationship in the semantic meaning. The model vector represents the characteristics of the SD evaluations and texture distance; therefore, a greater distance in the model vector, which is depicted by a darker shade of grey, implies a greater difference between the units.

4.3. Examination of Resulting SOM Map

As shown by the resulting SOM map in Figure 6, three distinctive type samples, D25, D50, and D76, are allocated at the three corners of the map. It is apparent that the surface texture certainly has an influence on the feeling generated by the mud wall. This means that the map represents

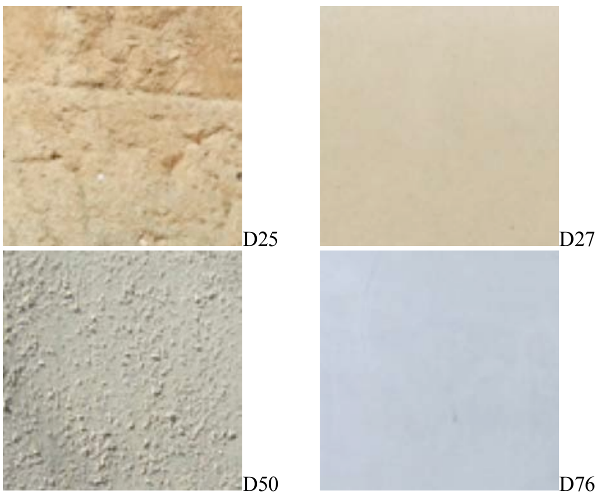


Figure 4: Images of the criteria for computing texture distance.

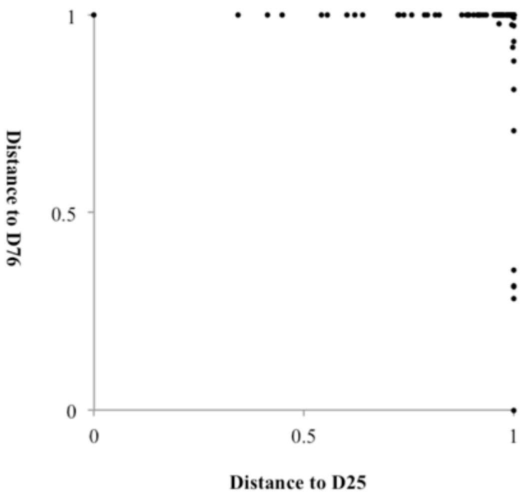


Figure 5: Distance of histogram for 90 samples (using D25 and D75 as criteria).

differences in texture according to the allocation of samples on the unit. Thus, the location of the map includes a correlation of the texture parameter (histogram). To confirm this correlation, Figure 7 summarizes the images near criterion D76. These samples are all white walls constructed using plaster, and thus the correlation of the surface texture is assured from the map location. Correlation of the location and texture surface was similarly confirmed for the other three samples. In a similar way, the photo images near sample D25 are also confirmed in Figure 8. As can be seen, the samples near D25 are aged, red-tinged walls. Thus, it is reasonable to conclude that the map location represents the variation in texture pattern. The samples are mapped according to the distance between the texture histogram and criteria. Thus, the location of a new wall to be built or maintained, can be mapped onto the resulting SOM map in order to compute the texture pattern. This means the SOM map can be used as a scale for mud wall textures.

Next, the scale of the affective evaluations was examined using the resulting SOM map. Figure 9 depicts an element of "beautiful", which is one of the evaluation words used as an input variable for the SOM. The gray scale of each unit on the 20 × 18 grid, extracted from the output unit of the resulting SOM map, indicates the element values (affective evaluation of "beautiful"). The location of the mapped samples is the same as in Figure 6. The white area means that the mapped sample on the unit has a "beautiful" image. It can be seen in Figure 9 that the area near sample D76 is the location of "beautiful" samples. The dark area implies an "ugly" meaning. Figure 10 shows a mapping of the primary affective words identified from the element maps. The correlation between the map location and affective meaning can be quantified from the resulting element values of the SOM map. For example, samples D25 and D50 correspond to "fantastic" and "ugly", respectively.

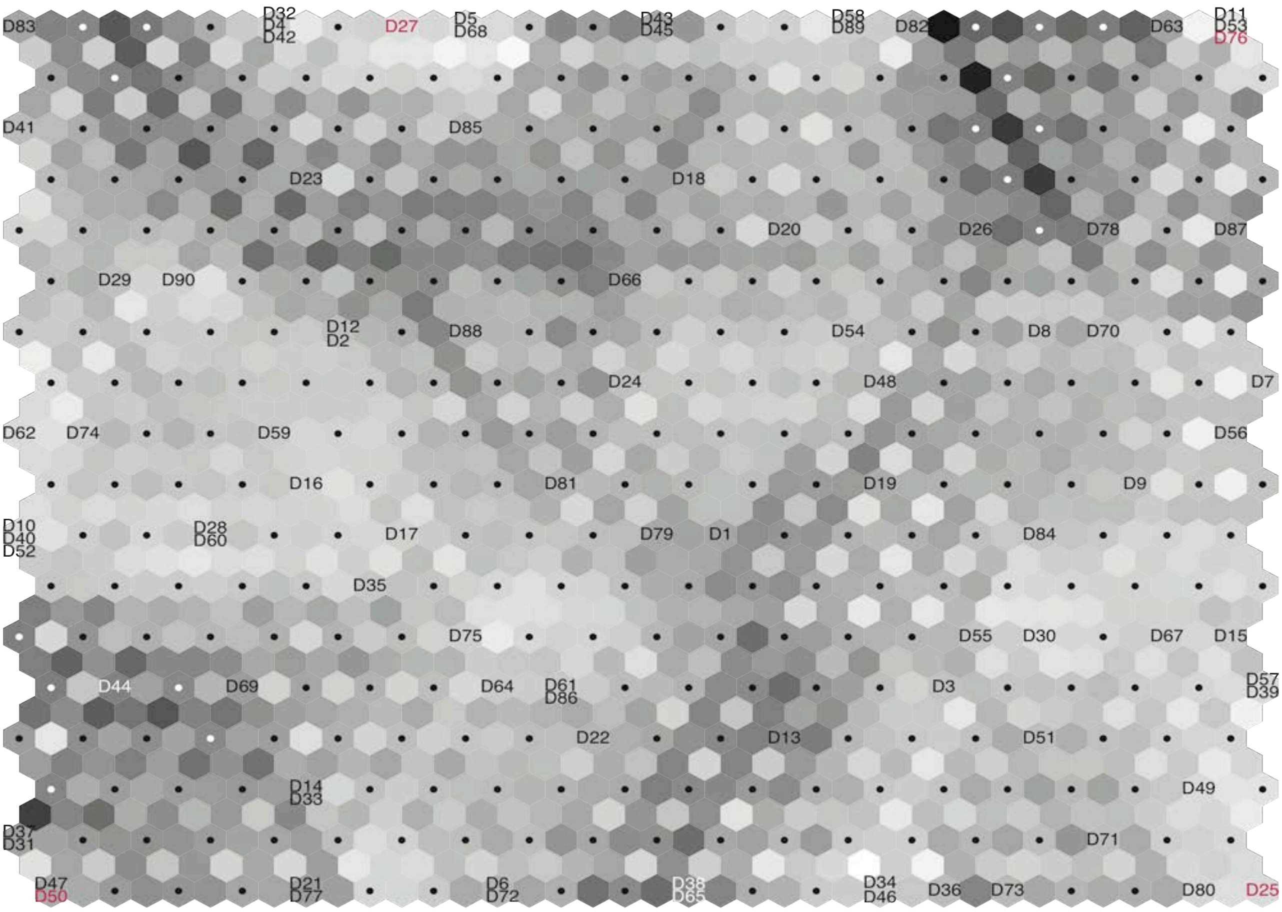
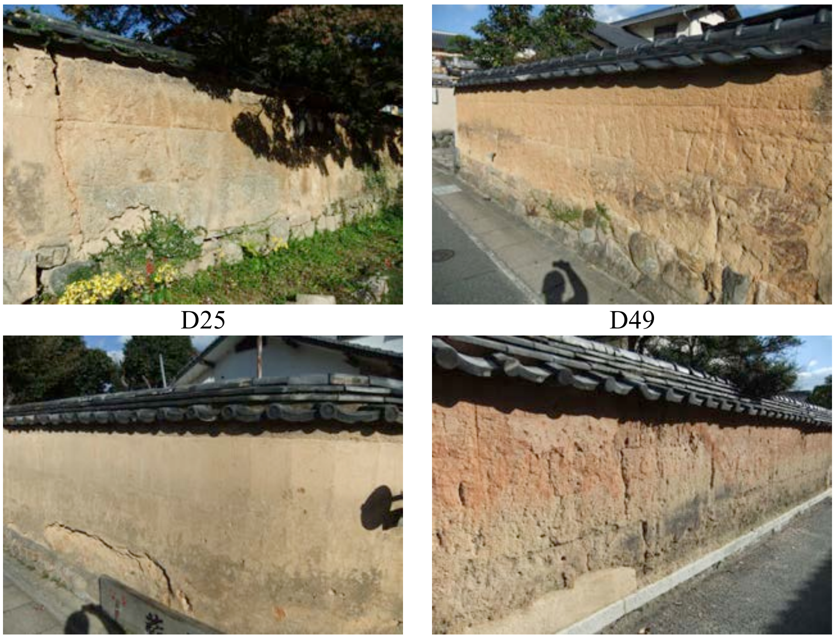


Figure 6: The resulting SOM map of 90 sample walls on 20 × 18 units.

D11 D53

D63 D76

Figure 7: Images allocated around sample D76.



D25 D49

D71 D80

Figure 8: Images allocated around sample D25.

Then, the correlation of the mud wall texture and affectiveness is mapped onto the output units. The map is used as an inference system to define the relationship between texture and affective value, because each unit is quantified by the 19 element values. The computed map can be used for streetscape assessment of the mud walls in Chofu's historic district. It can also be used for streetscape planning or review when building or maintaining mud walls.

5. CONCLUSIONS

The aim of this study was to analyze historic streetscapes in Chofu using affective engineering methodology. The distinctive mud walls are a landmark of the area, with their surfaces exuding a characteristic atmosphere of red-tinged color. We focused on researching the color effect of the mud wall surfaces. We investigated the color distribution of existing mud walls using display colorimetry with a color correction algorithm. Our investigation confirmed that the color distribution was sufficiently unified at present. We thus, formulated color guidelines using the Munsell color system based on the measured distribution.

Next, we created a SOM mapping through an affective experiment. We found that the SOM map identified the distances between the mud wall textures. A unit of the map also included the element value of the affective evaluation in the form of the location. Consequently, we were able to quantify

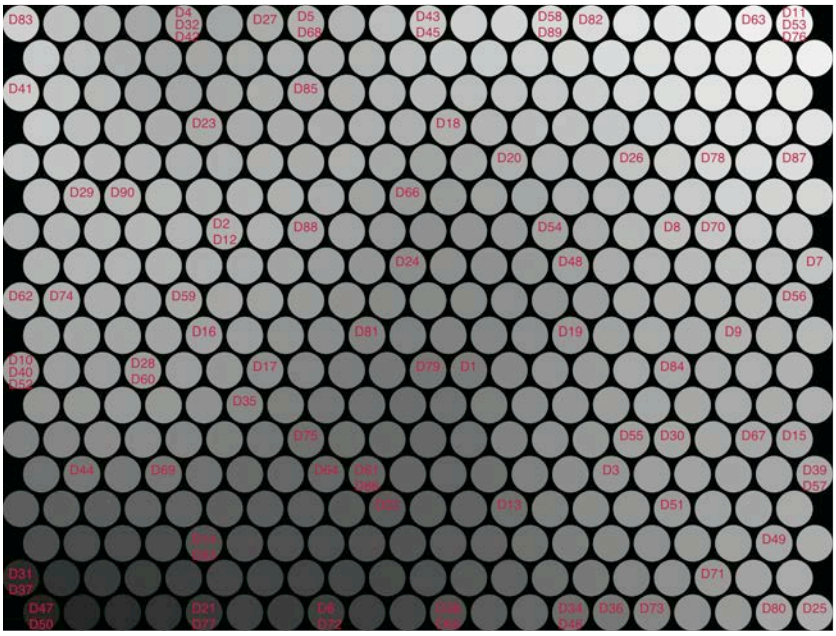


Figure 9: Element plane of the affective words “ugly” – "beautiful”.

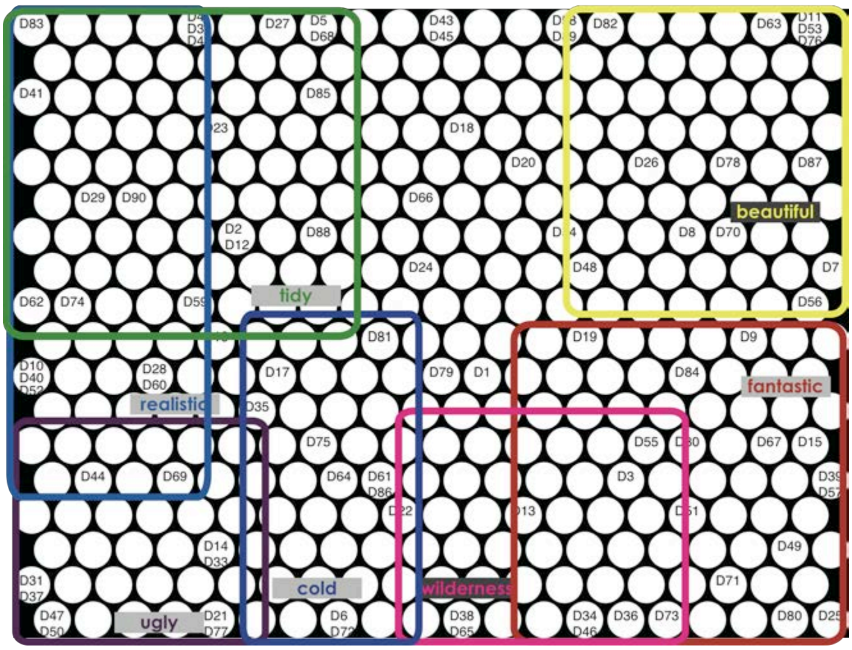


Figure 10: Overlapping affective meanings in the SOM mapping.

the relationship between mud wall texture and affectiveness. The results can be used for streetscaping in Chofu’s historic district.

A future issue is the measurement of the distance between wall textures. The Bhattacharyya distance between histograms of texture images was employed in this study. The obtained distribution on the two axes for the criteria is almost square. In other words, samples that are different to both criteria exist. These indefinable samples could not be mapped onto the unit. We therefore need to improve the definition accordingly.

REFERENCES

Nagamachi, M. (1995). A new ergonomic consumer-oriented technology for product development. Int’l. J. of Industrial Ergonomics, 15(1), 3-12.

Kohonen, T. (2001). Self-Organizing Maps. 3rd extended ed. New York, Springer.

Shiraki, W., et al. (2003). SOM を用いた住環境音の感性性能評価[Evaluation of Kansei performance on residential sound using SOM]. In S. Link & M. Kirchberg (Eds.), Proceedings of the 19th Fuzzy System Symposium (pp. 37-40), Japan.

Tsuchiya, T. (2006). Analysis of regional product design by Kansei engineering, Proceedings of the 3rd Int’l Conf. on Artificial Intelligence in Engineering & Technology (pp. 293-297), Kota Kinabalu, Malaysia.

Tsuchiya, T. (2013). Kansei Engineering Study for Streetscape Zoning using Self Organizing Maps. Int’l J. of Affective Engineering, 12(3), 365-373.

Tsuchiya, T. (2009). Kansei data analysis by self organizing maps and its application to regional brand analyses. Proceedings of the 17th World Congress on Ergonomics (IEA2009) [CD-ROM] Beijing, China.

Nakama, T. & Kinoshita, Y. (2010). A Kansei analysis of the streetscape in Kyoto - An application of the Kansei structure visualization technique. Proceedngs of the Int’l Conference on Kansei Engineering and Emotion Research (pp. 314-323), Paris, France.

BIOGRAPHY

Toshio Tsuchiya was educated as a system engineer at Hiroshima University and is currently a professor of Department of International Commerce in the Faculty of Economics at Shimonoseki City University. He received B.S. and M.S. degrees from Hiroshima University in 1990 and 1992 and received Ph.D in Information Engineering from Hiroshima City University in 2006. His research interests include data mining, knowledge engineering, fuzzy set theory and affective/kansei engineering.