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Quantification of Conspicuity Using Optical Properties and Evaluation of Impression of Pseudo-Fingerprints on Touch Panels

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ABSTRACT

The installation rate of touch panels in automobiles is increasing progressively, and as displays continue to grow in size, improvements in their visibility has become important. In this study, we quantified the visibility of touchscreens used in automobiles by evaluating the relationship between optical characteristics and impression evaluation. Specifically, we assessed the impressions and luminance of pseudo-fingerprints on touchscreens using a simulated in-vehicle environment and sunlight. From the impression evaluation experiment of the touch panel at the light source position, a positive correlation was confirmed between the conspicuousness score and luminance ratio through factor analysis. Based on the results of the conspicuousness evaluation experiment of pseudo-fingerprints in the illuminance change, a multiple regression analysis was performed, suggesting that the objective variable of the conspicuousness evaluation of pseudo-fingerprints could be explained by panel and optical characteristics.

Keywords: Evaluation impression, Conspicuity, Pseudo-fingerprint, SD method, Multiple regression analysis

INTRODUCTION

In recent years, the demand for touch panels has increased considerably owing to the widespread use of electronic devices like smartphones. Consequently, the development of high-performance touch panels with superior conspicuity is needed. Specifically, the automotive industry is believed to be undergoing a once-in-a-century technological revolution owing to advancements in information technology (IT). Consequently, the amount of information processed by users in cabin spaces has surged in recent years. To address this issue, the adoption rate of touch panels as user interfaces (UI) for intuitive information control has progressively increased. Moreover, the design trend for in-vehicle spaces has shifted towards larger displays. However, improvement in the visibility of these displays is necessary because the current visibility evaluation is often conducted using sensory evaluation and lacks quantification. To quantify the visibility of touchscreens used in automobiles, we evaluated the relationship between optical characteristics and impression evaluation by assessing the impression and luminance of pseudo-fingerprints on touchscreens using a simulated in-vehicle environment and pseudo-sunlight.

EXPERIMENTAL METHOD

Experiment Environment

The experimental setting consisted of a dark room that simulated the environment inside a car. As depicted in Figure 1, the dark room was designed to mimic the actual in-vehicle environment by determining the positional relationship between the participant and touch panel. Additionally, the position and angle of the touch panel were adjusted. Each participant's gaze was fixed using a chin rest. The positions of the touch panel and chin rest were adjusted to correspond to an actual in-vehicle environment. The darkroom was equipped with a pseudo-sunlight illumination that could be affixed to an aluminum frame to modify the position of the illumination.

Evaluation Touch Panel

We employed eight touchscreens featuring lipophilic and oleophobic properties. Pseudo-fingerprints were uniformly applied to the surfaces of the touchscreens, and their appearance varied among the touchscreens.

Pseudo-Fingerprint

Table 1 lists the transfer conditions for the pseudo-fingerprints. Twenty drops of a pseudo-fingerprint liquid were carefully administered to form a

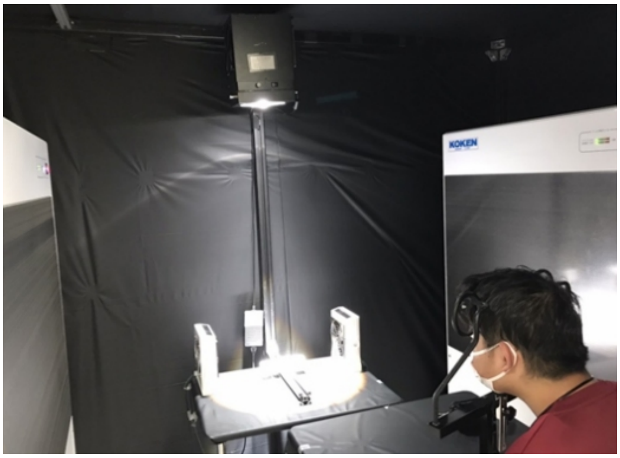

Figure 1: Experimental environment.

Table 1. Transcription condition.

Temperature	25°C
Humidity	50%
Drop Volume	0.8 ml
RPM (Low Speed)	500 RPM
RPM (High Speed)	1100 RPM
Transcription Power	50 N

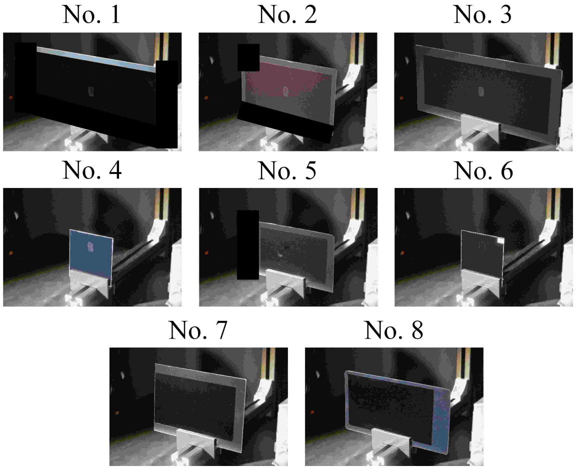

Figure 2: Sample panels.

consistent and uniform thin film on the spinning surface of a spin coater. A transfer force of 50 N was applied to prevent the crushing of the pseudo-fingerprints and enable a clear confirmation of the transfer. The sample numbers for the pseudo-fingerprints on the eight touchscreens are illustrated in Figure 2.

Lighting Condition

Figure 3 depicts the simulated positional relationship of each lighting condition, namely the up, side, and reflected conditions. A pseudo-solar illumination source (SOL-600-01D05, Tsubosaka Electric Co.) was used as the light source.

EVALUATION EXPERIMENT OF TOUCH PANEL IMPRESSION

Experimental Procedures

The perception of touch panels coated with pseudo-fingerprints was assessed by ten adult males. The Semantic Differential method was used to appraise perceptions, and Visual Analog Scale (VAS) served as an assessment metric. Eleven pairs of adjectives, including terms related to filth, were generated based on previous studies (Muto, 1998). These are listed in Table 2. The above-mentioned lighting conditions were employed, and the illuminance of

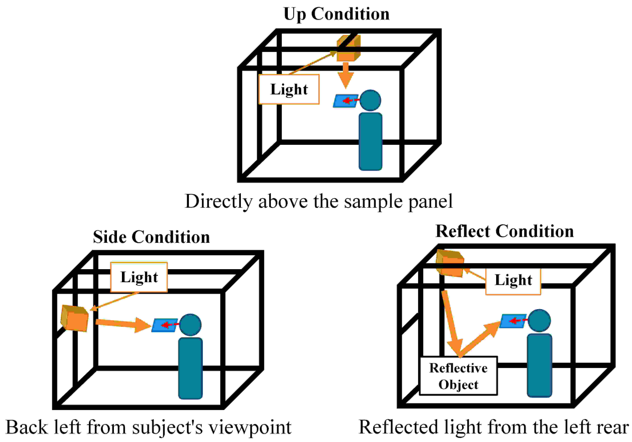

Figure 3: Light source positions.

Table 2. Adjective pairs.

Dislike	Like
Old	New
Mundane	Unique
Dirty	Clean
Jumble	Clear
Sober	Flashy
Frivolous	Massive
Hidden	Visible
Negligible	Noticeable
Cold	Warm
Sticky	Smooth

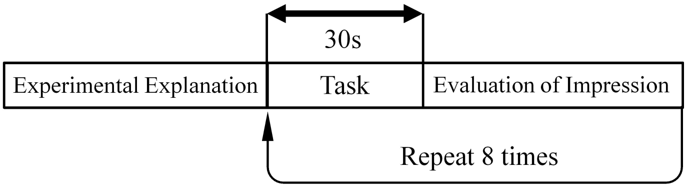

Figure 4: Experimental protocol.

both the touch panel and image was fixed at 20000 lx. The experimental procedure is illustrated in Figure 4. After the procedure was explained, the participants gazed at the touchscreens for 30 s, and then passed on the tablet to appraise their perception of the touchscreens using pseudo-fingerprints. The presentation order of the touchscreens was randomized, and impression evaluation was performed for each of the eight touchscreens under different lighting conditions. The luminance of touchscreens with pseudo-fingerprints was measured. The luminance meter gauged the luminance of each touch panel at two locations–one with fingerprints and the other without–from the gaze position of the participant. Luminance with fingerprints was measured at the center of the fingerprints, and luminance without fingerprints was measured 10 mm to the left of the center of the fingerprints.

RESULTS

Factor analysis was performed on the data collected from 10 subjects. Based on the scree plot of eigenvalues, the number of factors was determined to be three. The results of the factor–matrix calculations are listed in Table 3. After careful consideration, the factors calculated from the results were named. Factor names were selected based on absolute values being 0.4 or higher. The first factor exhibited high values for various attributes, including prominence, hygiene, and likeability, as well as dichotomies like "Dirty-Clean," "Old-New," and "Dislike-Like." It was named the "conspicuousness factor." The second factor demonstrated high values for universality and artistry related to fingerprints, such as "Mundane-Unique" and "Sober-Flashy," and was therefore named the "Artistic factor." Factor 3 showed high values for terms related to the materiality of fingerprints, such as "Cold-Warm" and "Frivolous-Massive." Consequently, the third factor is called the "materiality factor." The outcomes of the first factor scores are shown in Figures 5 and 6. Steel-Dwass multiple comparison tests were conducted between the lighting conditions and each touch panel, revealing significant differences between the lighting conditions and touch panels for several items. The luminance ratio, which is the ratio of the fingerprint area to the touch panel area, was used in a previous study to obtain luminance measurement results (Nakamura, 2000). Figure 7 demonstrates the correlation between the luminance ratio and Factor 1 scores. The correlation coefficient between the luminance ratio and first factor score was 0.47. The correlation coefficients for the up, side, and reflected lighting condition were 0.65, 0.51, and 0.86, respectively.

Table 3. Factor matrix computation.

	Factor1	Factor2	Factor3
Dislike-Like	−0.873	−0.043	−0.045
Old-New	−0.838	0.203	−0.264
Mundane-Unique	−0.362	0.672	0.084
Dirty-Clean	−0.834	−0.187	0.276
Jumble-Clear	−0.686	−0.256	−0.334
Sober-Flashy	−0.323	0.721	0.159
Frivolous-Massive	−0.218	0.015	0.229
Hidden-Visible	−0.456	−0.108	0.159
Negligible-Noticeable	0.351	0.385	−0.212
Cold-Warm	0.051	0.242	0.316
Sticky-Smooth	−0.706	−0.237	0.199

Discussion

Table 3 illustrates that factor 1 coefficient is negative, indicating that higher the factor 1 score, more salient the pseudo-fingerprints and smudges on the touch panel. As shown in Figure 5, significant differences were observed in

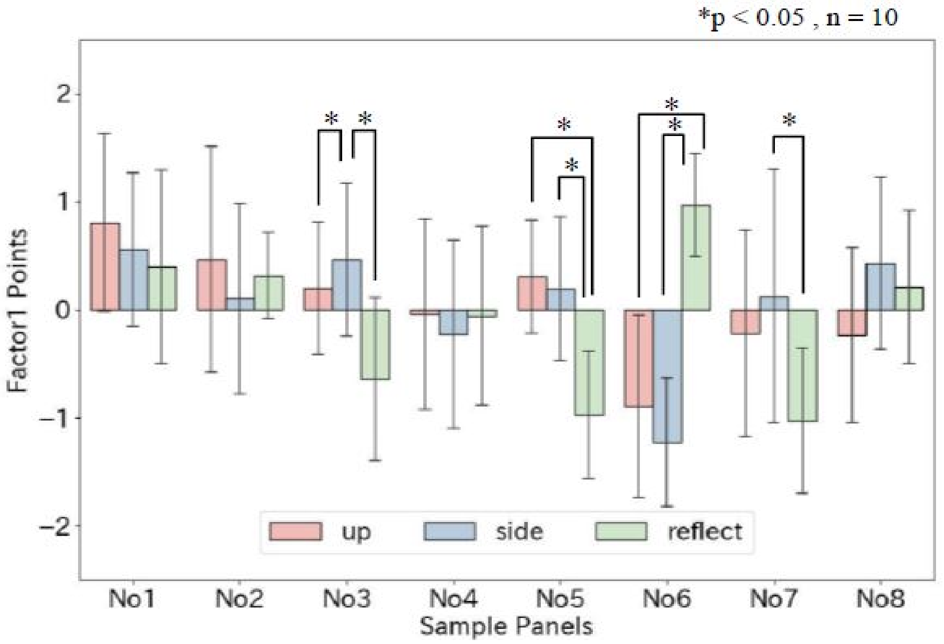

Figure 5: Factor 1 score (sample panels).

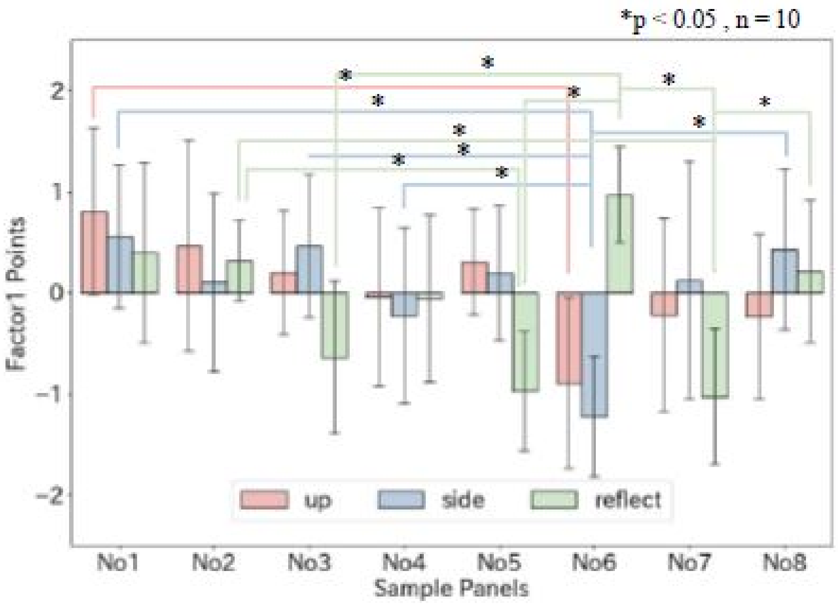

Figure 6: Factor 1 score (lighting condition).

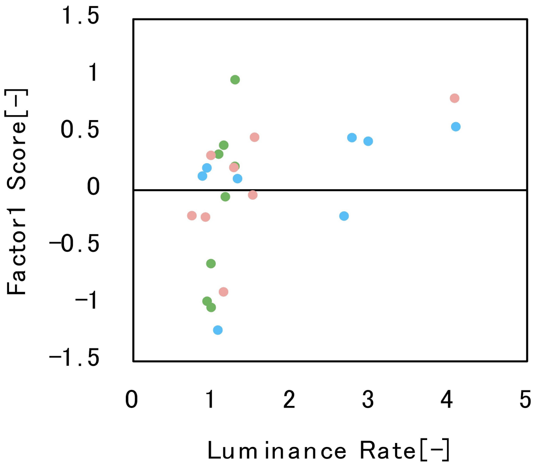

Figure 7: Relationship between factor 1 point and luminance rate.

only one item in the Up condition. In the Side condition, significant differences were observed in four items, while in the Reflect condition, significant differences were observed in six items. This discrepancy could be attributed to the way the illumination hit the touch panel, which is believed to have amplified the distinction between the two conditions. Figure 7 shows a positive correlation between the luminance ratio and factor 1 score, indicating that the luminance ratio, which is an optical characteristic, can be used to quantitatively evaluate the salience of a touch panel. Additionally, the relationship with lighting condition exhibited a stronger correlation than the overall correlation, suggesting that lighting position impacts conspicuousness.

EXPERIMENT TO EVALUATE THE CONSPICUSITY OF PSEUDO-FINGERPRINT BY CHANGING ILLUMINANCE

Experimental Procedures

To assess the connection between the optical properties of pseudo-fingerprints and the perceptual evaluation of fingerprint conspicuity, conspicuousness assessment experiments were performed on eight adult males. VAS was used as the conspicuousness assessment scale, and five lighting conditions were employed: 4000, 8000, 12000, 16000, and 20000 lx. Following an explanation of the procedure, the participants were seated in a chair and the chinstrap was adjusted. They then evaluated the pseudo-fingerprints on the touch panel. The presentation order of the touchscreens was randomized, and each illumination condition was assessed for eight touchscreens. The luminance of touchscreens with pseudo-fingerprints was measured. The luminance meter gauged the luminance at two spots on each touch panel—one with fingerprints and the other without fingerprints—from the gaze point of the participant. The luminance with fingerprints was measured at the center of the fingerprints, and the luminance without fingerprints was measured 10 mm to the left of the center of the fingerprints.

Result

Figures 8 and 9 show the results of conspicuity evaluation. Steel-Dwass multiple comparison tests were conducted for illuminance conditions and for each touch panel. The tests revealed significant differences between the illuminance conditions for touch panels No. 1 and No. 3 between the 4000 and 16000 lx conditions and between the 4000 and 12000 lx conditions for touch panel No. 7. Additionally, significant differences were observed among touchscreens in terms of luminance ratio and conspicuity evaluation. Figure 10 depicts the relationship between the luminance ratio and conspicuity evaluation. The correlation coefficient between luminance ratio and conspicuity evaluation was 0.40, indicating a weak positive correlation. Multiple regression analysis was performed to predict the objective variables using multiple explanatory variables. It was assumed that touch panel characteristics, such as oleophilic and oleophobic properties, play a significant role in the evaluation of luminance and conspicuity. The objective variable was the conspicuity evaluation, and explanatory variables were selected from HAZE (whiteness), reflective imaging, gloss, SCI (total reflectance), SCE (diffuse reflectance), oleic acid contact angle, fingerprint luminance, touch panel luminance, and luminance ratio, with the explanatory variable having the lowest AIC (Ninomiya, 1999). The explanatory variables with the lowest AIC were SCI_Y, SCI_b, SCE_a, SCE_b, oleic acid contact angle, touch screen luminance, and luminance ratio, with the coefficient of determination at 0.78.

Discussion

Figure 8 shows that, for all the different illumination conditions tested, there was a statistically significant contrast in the conspicuousness of the

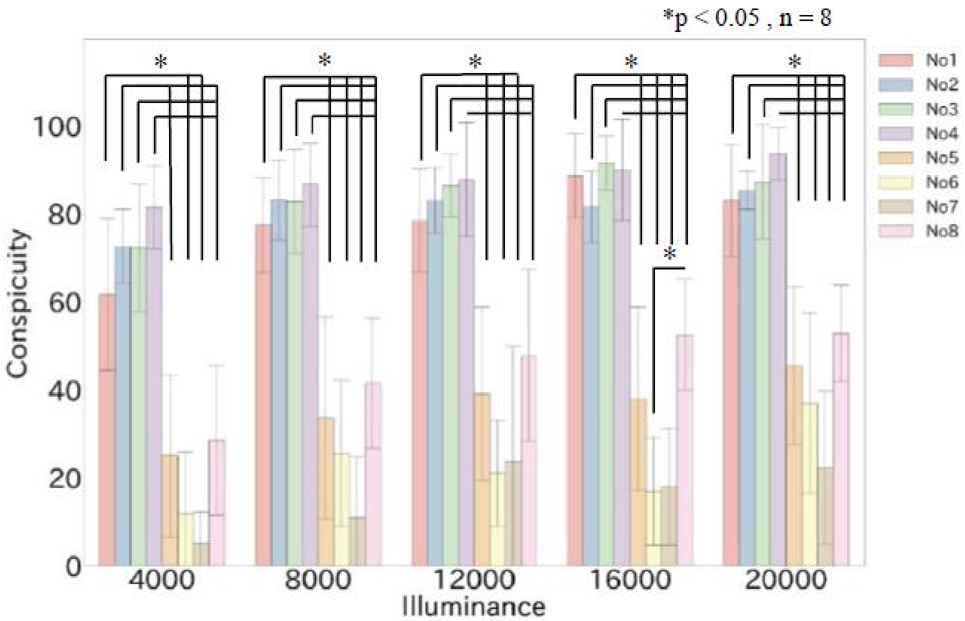

Figure 8: Conspicuity score (Illuminance).

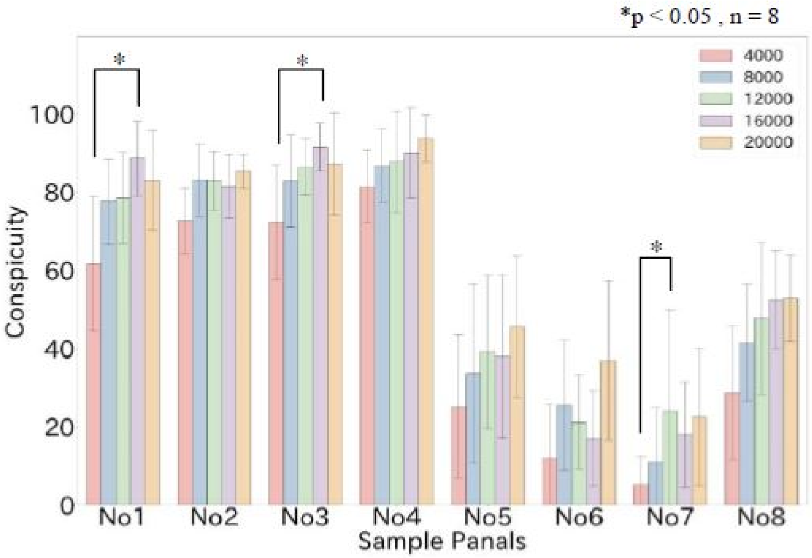

Figure 9: Conspicuity score (sample panels).

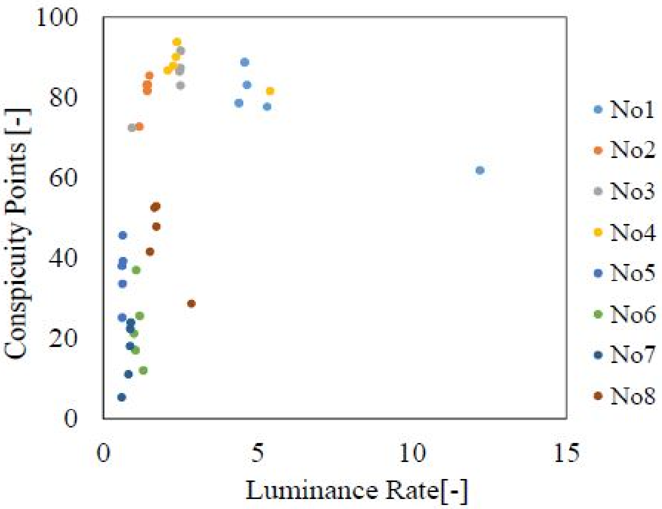

Figure 10: Relationship between conspicuity points and luminance rate.

fingerprints between touchscreens that were oleophobic (No. 1 to No. 4) and those that were oleophilic (No. 5 to No. 8), except for No. 1 and No. 5 and No. 1 and No. 8. However, Figure 9 shows that only three touchscreen illumination conditions demonstrated significant differences. This result indicates that the impact of touch-panel characteristics on conspicuity is more substantial than the change in conspicuity caused by alterations in illumination. Figure 10 demonstrates a positive correlation between the luminance ratio and conspicuity for touchscreens No. 2, No. 3, and No. 7, and a negative correlation for touchscreens No. 1, No. 4, No. 6, and No. 8, suggesting that the properties of the touchscreens may have a noteworthy

Table 4. Multiple regression analysis.

	β	SE	t	p
Consta	53.1001	7.272	7.302	<0.001
SCI_Y*	−13.5024	2.068	2.068	<0.001
SCI_b*	3.0024	0.569	0.569	<0.001
SCE_a*	−42.5419	6.185	−6.879	<0.001
SCE_b*	−7.2681	2.348	−3.095	0.002
Oleic acid contact angle	0.5631	0.067	8.409	<0.001
Panel brightness	2.8744	0.622	4.621	<0.001
Brightness ratio	−1.9034	0.677	−2.810	0.005

influence on conspicuity. Table 4 indicates that the oleic acid contact angle had the highest absolute t-value. This indicates that differences in the oleophilic and oleophobic characteristics of touch panels have a significant effect on conspicuity.

CONCLUSION

In this study, we aimed to quantify the conspicuousness of touchscreens employed in automobiles by examining the correlation between their optical characteristics and impression evaluations. Specifically, we scrutinized the impressions and luminance of simulated fingerprints on touchscreens under simulated sunlight and in a simulated in-vehicle environment. Our findings revealed that dissimilarities in the oleophilic and oleophobic attributes of touch panels have a substantial impact on conspicuity. Multiple regression analysis showed that the conspicuousness of fingerprints can be quantified using touch-panel characteristics and optical attributes. In future, we intend to gather data to enhance the accuracy of the multiple regression model and establish a model that does not rely on the position of the light source, thereby enabling the quantification of visibility by optical attributes.

REFERENCES

Muto, H., Miki, K., Kojima, T., Matsubara, M. (1998). Psychologiea1 evaluation of stain on the impression of building exterior. Japan Society for Finishing Technology Volume 1998 No. 915.

Nakamura, Y. (2000). A Technique for Quantitatively Examining Luminance Contrast in Lighting Environment. Journal of Science and Technology in Lighting Volume 84 No. 8.

Ninomiya, S. (1999). AIC (Akaike Information Criterion). Nippon shokuhin kagaku kogaku kaishi Journal of the Japanese Society for Food Science and Technology Volume 46 No. 1.