Original Paper *Forma*, **17**, 239–251, 2002

Statistical Correlation between Quantificational Indices and Preference Judgements of Structural Landscapes

Humihiko GOTOU[1]*, Yukari SAKURAGI[2] and Tetsuo IWAKUMA[3]

[1]*Faculty of Engineering and Resource Science, Akita University, Tegata-gakuen-mati, 1-1, Akita 010-8502, Japan*
[2]*Graduate School of Frontier Sciences, The University of Tokyo, Hongo, 7-3-1, Bunkyo-ku 113-8656, Japan*
[3]*Department of Civil Engineering, Tohoku University, Aza, Aoba 06, Aramaki, Aoba-ku, Sendai 980-8579, Japan*
**E-mail address: gotou@ce.akita-u.ac.jp*

(Received October 21, 2002; Accepted November 15, 2002)

Keywords: Quantification of Landscape, Scenic Beauty, Preference Judgement

Abstract. We proposed objective quantificational indices for a relation between contour lines of a structure and its background in line drawings utilizing wavelet and spectral analyses. We carried out multiple regression analyses for each preference judgement point given by a questionnaire survey as a criterion variable using the quantificational indices as explanatory variables. Considering results of these multiple regression analyses we discuss a possibility to explain one's preference for landscapes in terms of the objective quantificational indices.

1. Introduction

Studies on scenic beauty evaluation of landscapes using quantification of forms have been reported in really various fields such as structural design, urban planning, forest management, ecology landscape and so on (SUGIYAMA *et al.*, 1989, 1991; ISE and IWAKUMA, 1994; KALIDINDI *et al.*, 1997; GOTOU *et al.*, 1999; YASUDA *et al.*, 2001; GOROMARU and TERASAWA, 2001; HANDS and BROWN, 2002; STAMPS, 2002). One of the main themes of this kind of studies is how to explain subjective preference of people by objective quantificational tools. While the subjectiveness of people is generally investigated by simple questionnaires (YASUDA *et al.*, 2001; HANDS and BROWN, 2002), there are many studies intended to objectively quantify graphical characteristics of landscapes using various tools such as fractal dimension, RGB value, spectral analysis and so on (KALIDINDI *et al.*, 1997; GOTOU *et al.*, 1999; STAMPS, 2002). In case of designs of civil engineering structures such as bridges, beside the relation between the subjectivity and objectivity, how to estimate harmony between a structure and its background is another theme and there are studies intended to quantify the relation between a structure and its background using psycho-vector, spectral analysis, fractal dimension and so on (SUGIYAMA *et al.*, 1989,

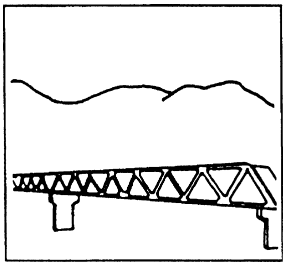

Fig. 1. A, mt.

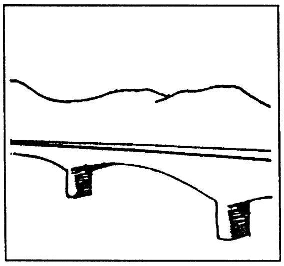

Fig. 2. B, mt.

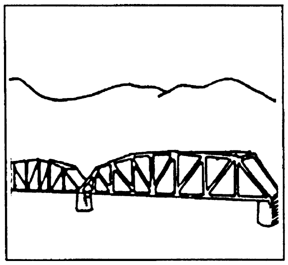

Fig. 3. C, mt.

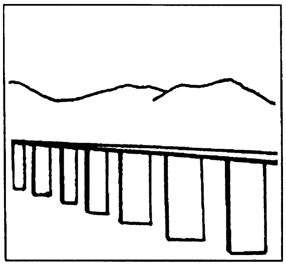

Fig. 4. D, mt.

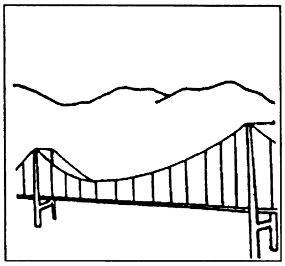

Fig. 5. E, mt.

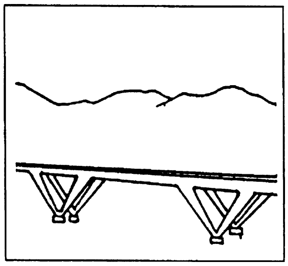

Fig. 6. F, mt.

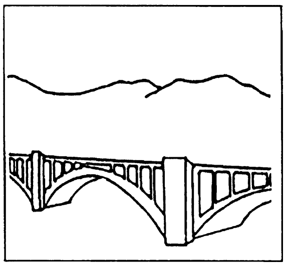

Fig. 7. G, mt.

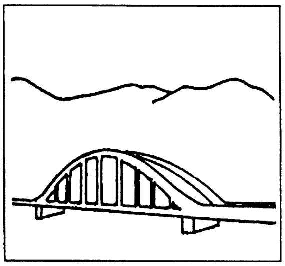

Fig. 8. H, mt.

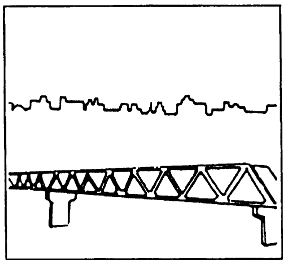

Fig. 9. A, bldg.

1991; ISE and IWAKUMA, 1994; GOTOU *et al.*, 1999; GOROMARU and TERASAWA, 2001). In these studies skylines of a structure and its background are often numerically tractable elements and it is suggested that the skylines play an important role in scenic beauty (KAMEI, 1992; STAMPS, 2002). In this study we try to quantify one wave given by a convolution between skylines of a bridge and of its background, instead of quantifying relations between the two skylines, and investigate statistical correlation between the quantified indices and preference judgements of examinees. A concrete flow of this study is as follows. Firstly, we propose some indices which quantify a wave given by a convolution between contour lines of a structure and its background in landscape design proposals drawn as easy line drawings. Secondly we conduct a questionnaire survey in which examinees give preference judgements for the line drawings. Then we carry out multiple regression analyses for the preference judgement point as a criterion variable using the quantified indices as explanatory variables. And we discuss about statistical significance of the regression using the indices.

2. Quantification

2.1. Extraction of contour lines

In this study a main structure and its background drawn as an easy line drawing projected on a 2-dimensional rectangular frame (as shown in Figs. 1–9) are chosen as objects of the following analyses for simple quantification. We extract contour lines of the structure and its background and carry out spectral analyses by the following two manners.

Manner I: We extract a contour line from the background and another contour line from the structure (Fig. 10a) respectively. Regarding the contour line of the structure as a mother wavelet, we calculate power spectrums of a convolution between the mother wavelet and the contour line of the background (GOTOU *et al.*, 1999).

Manner II: We extract a contour line from the background and three contour lines from the structure (an upper contour line, a middle contour line and a lower contour line as shown in Fig. 10b). Regarding each contour line of the structure as a mother wavelet, we calculate power spectrums of a wave given as summation of the three convolution waves between each mother wavelet and the contour line of the background (GOTOU *et al.*, 1999).
The contour line of a background is defined as a boundary line between the sky and the background except the sky. The contour line of a structure in Manner I is extracted in the same way as extracting the middle contour line of a structure in Manner II. The upper contour line of the structure is defined as a boundary line between the background and the upper surface of the structure. The lower contour line of the structure is defined as a boundary line between the lower surface of the structure and the background. The middle contour line of the structure is defined in the following way.

1. The contour line starts from the left edge of the boundary line between the visible roadbed and background in the frame and go in the right direction.

2. In the case when the boundary line of the roadbed and the background bifurcate, the bifurcated line which makes the smallest counterclockwise angle from the reference line shown as Fig. 11 is chosen in principle.

3. Only bifurcated lines which make counterclockwise angle of 0°~180° from the reference line are chosen so that the contour line can be described as a single-valued function.

4. Only in the case when bifurcated lines exist in the direction of both 90° and 180° from the reference line, the bifurcated line in the direction of 180° is chosen so that vertical members are included.

Representing a contour line of the structure by a mother wavelet $\psi(x)$ and a contour line of the background by a signal $f(x)$ respectively, we define a convolution between them by the following equation (GOTOU *et al.*, 1999).

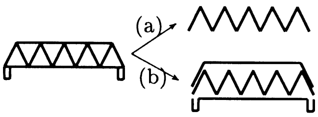

Fig. 10. Extracted line.

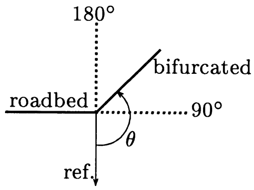

Fig. 11. Bifurcated line.

$$W(c) = \int_{-\infty}^{\infty} \psi(x-c) f(x) dx. \tag{1}$$

The origin of the vertical axis from which the contour line of the structure is numerically extracted is decided so that $\psi(x)$ satisfy the following condition.

$$\int_{-\infty}^{\infty} \psi(x) dx = 0. \tag{2}$$

Since Eqs. (1) and (2) cannot be used for discretized data, the following equations are used instead of the actual calculation.

$$W_i = \frac{1}{\Delta c} \sum_{j=0}^{M-1} \psi_{M-j} \cdot f_{i-j} \tag{3}$$

$$\frac{1}{\Delta c} \sum_{i=1}^{M} \psi_i = 0 \tag{4}$$

where ψ_i and f_i are discretized data for a structure and a background respectively; M is data number of ψ_i; W_i ($i = 1, ..., N$) are values of discrete convolutions for a data interval Δc.

2.2. *Quantificational indices*

In order to represent ‘characteristics’ of the convolution waves obtained by Manner I and Manner II, we introduce the following indices.

(1) P_e*, Standard deviation*

As an index to represent an amplitude of the convolution wave $W(c)$, we define ‘Standard deviation’ P_e, that is a standard deviation of $W(c)$, by the following equation,

$$P_e = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(W_i - \overline{W}\right)^2} \tag{5}$$

where n is data number; $\overline{W}$ is an average of W_i. The index suggest similarity between contour lines of a structure and of its background (GOTOU *et al.*, 1999).

(2) R_p, Ratio of positive data

As an index to represent a ratio of positive data of $W(c)$ against the total data, we define 'Ratio of positive data' R_p by the following equation.

$$R_p = \frac{\text{number of positive data of } W_i}{N\left(\text{total data number of } W_i\right)} \times 100(\%). \tag{6}$$

If plus and minus of the mother wavelet data are upside down opposite, also opposite plus and minus of W_i are given. While the index P_e does not distinguish the difference, the index R_p represent partial incidence of concaveness and convexness of the contour lines.

(3) a, Gradient of spectrums

As an index to represent a gradient of the line regressed from log-log plots of P, power spectrums of $W(c)$ in the vertical coordinate and of $1/T$, spacial frequency in the horizontal coordinate, we define 'Gradient of spectrums' a by the following equation.

$$\ln P = b - a \ln \frac{1}{T}. \tag{7}$$

The index (not absolute value) generally has a greater value, when frequencies of the contour lines are higher.

(4) i, Dispersion of spectrums

As an index to represent a normalized standard deviation of spectrums against the regressed line in the previous subsection, we define 'Dispersion of spectrums' i by the following equation.

$$i = \sqrt{\frac{\sum_{j=l/2}^{i} \left\{\ln P(j) - \left(b - a \ln \frac{j}{T_1}\right)\right\}^2 \left\{\Delta\left(\frac{j}{T_1}\right)\right\}}{\frac{l}{T_1} - \frac{l/2}{T_1}}}. \tag{8}$$

When the index has lower value, it means that the distribution of P is similar to $1/f$ fluctuation (KAMEI, 1992).

3. Examples of Quantificational Analyses

We analyze 16 line drawings. On each of them one of 2 backgrounds: 'Mountains'/ 'Buildings' and one of 8 bridges A~H are drawn. Examples in case of the background 'Mountains' are shown in Figs. 1–8 for bridges A~H and an example in case of the background 'Buildings' for the bridge A is shown in Fig. 9. Examples of contour lines

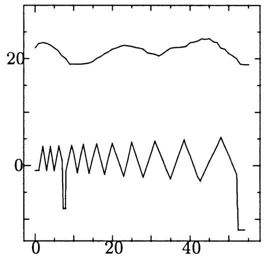

Fig. 12. I, A, mt.

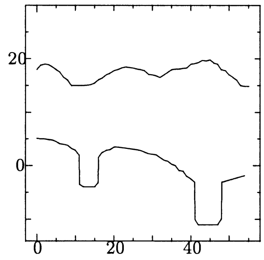

Fig. 13. I, B, mt.

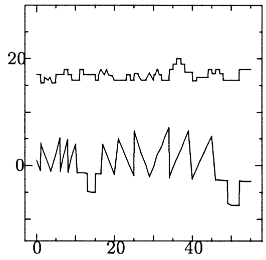

Fig. 14. I, C, bldg.

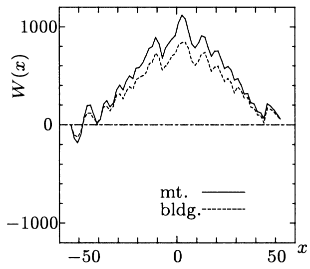

Fig. 15. $W(x)$ (I, A).

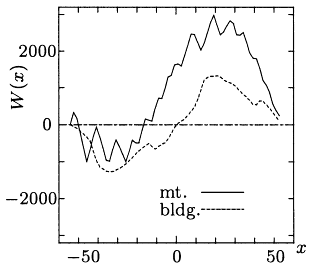

Fig. 16. $W(x)$ (I, B).

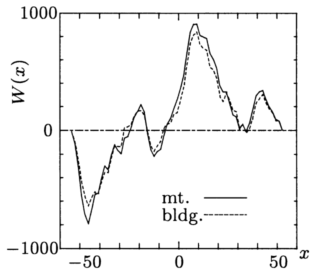

Fig. 17. $W(x)$ (I, C).

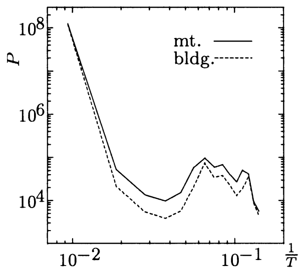

Fig. 18. Power (I, A).

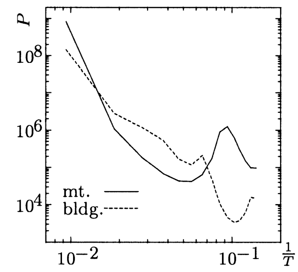

Fig. 19. Power (I, B).

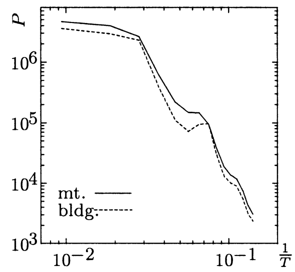

Fig. 20. Power (I, C).

extracted by Manner I from the drawings are shown in Figs. 12–14. Examples of convolutions between the contour line of those bridges as a mother wavelet and the contour line of each background (‘Mountains’ as ‘mt.’/‘Buildings’ as ‘bldg.’) are shown in Figs. 15–17. Examples of power spectrums obtained from the convolutions by Manner I are shown in Figs. 18–20. The indices derived from the convolutions and the power spectrums for the 16 drawings in Manner I are shown in Tables 1 and 2 in case of the backgrounds ‘Mountains’ and ‘Buildings’ respectively. Each index derived for 8 bridges are normalized so that their average value is 0 and that their variance value is 1.

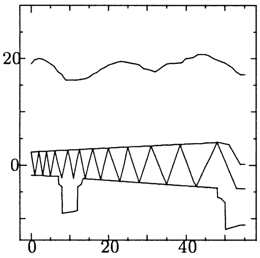

Fig. 21. II, A, mt.

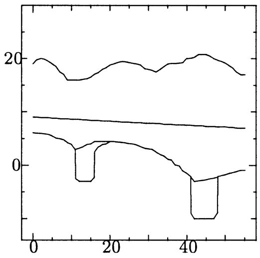

Fig. 22. II, B, mt.

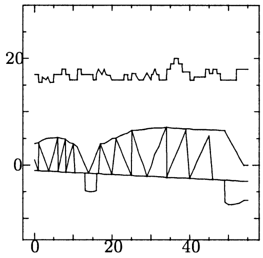

Fig. 23. II, C, bldg.

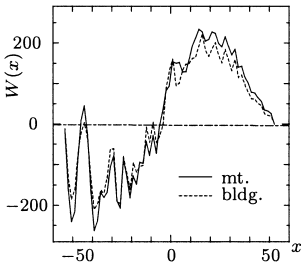

Fig. 24. $W(x)$ (II, A).

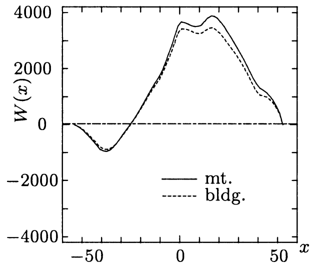

Fig. 25. $W(x)$ (II, B).

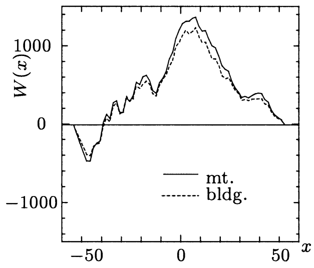

Fig. 26. $W(x)$ (II, C).

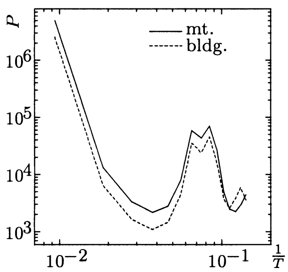

Fig. 27. Power (II, A).

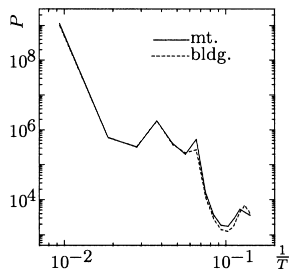

Fig. 28. Power (II, B).

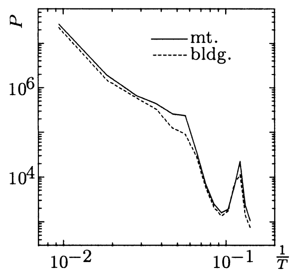

Fig. 29. Power (II, C).

Examples of contour lines extracted by Manner II from the drawings are shown in Figs. 21–23. Examples of sum of three convolutions between one of the three contour lines for each bridge as a mother wavelet and the contour line of the background are shown in Figs. 24–26. Examples of power spectrums obtained from the (summed) convolutions by Manner II are shown in Figs. 27–29. The indices derived from the convolutions and the power spectrums for the 16 drawings in Manner II are shown in Tables 3 and 4 in case of the backgrounds 'Mountains' and 'Buildings' respectively. Each index derived for 8 bridges are normalized so that their average value is 0 and that their variance value is 1.

Table 1. Values of indices (Manner I, Mountains).

Bridge	P_e	R_p	a	i
A	−0.794	1.866	0.748	0.097
B	1.448	−0.286	0.251	1.099
C	−0.667	−0.958	−0.256	−1.173
D	1.448	−0.286	0.251	1.099
E	−1.284	0.387	1.830	−1.123
F	−0.040	0.656	−1.327	0.714
G	−0.247	−0.017	−0.651	−1.123
H	0.135	−1.362	−0.846	0.411

Table 2. Values of indices (Manner I, Buildings).

Bridge	P_e	R_p	a	i
A	−0.869	1.676	0.889	0.624
B	0.827	−1.511	−0.967	−0.554
C	−0.637	−0.302	−0.057	−1.000
D	1.801	−0.082	0.431	1.450
E	−1.334	0.247	1.827	−1.081
F	0.093	0.687	−1.107	0.842
G	−0.180	0.357	−0.454	−0.942
H	0.298	−1.072	−0.562	0.660

Table 3. Values of indices (Manner II, Mountains).

Bridge	P_e	R_p	a	i
A	−1.036	−1.151	1.599	0.656
B	1.250	0.437	−1.381	−0.176
C	−0.528	1.866	−0.927	−0.804
D	1.754	0.119	1.037	2.614
E	−0.779	−1.151	0.126	−1.301
F	−0.433	0.119	0.235	−1.190
G	−0.421	0.437	0.040	−2.331
H	0.193	−0.675	−0.729	2.533

Table 4. Values of indices (Manner II, Buildings).

Bridge	P_e	R_p	a	i
A	−1.017	−1.323	1.755	0.360
B	1.236	0.496	−1.326	0.013
C	−0.527	1.819	−0.895	−0.764
D	1.767	0.165	0.935	1.589
E	−0.782	−0.992	0.107	−0.510
F	−0.443	0.000	0.173	−0.499
G	−0.435	0.496	−0.090	−1.367
H	0.202	−0.661	−0.659	1.177

Table 5. Questionnaire (Mountains).

	A	B	C	D	E	F	G	H
Av.	3.33	2.48	3.07	2.86	4.00	2.74	2.98	3.12
Dev.	1.08	0.91	1.22	1.08	1.05	0.95	1.14	1.07

Table 6. Questionnaire (Buildings).

	A	B	C	D	E	F	G	H
Av.	2.95	2.69	2.48	2.60	4.00	2.67	3.36	3.17
Dev.	1.00	1.23	1.10	1.31	1.11	1.02	1.09	1.02

4. Questionnaire Survey

We carried out a questionnaire survey for 42 examinees (3rd grade students majoring civil engineering in Tohoku Univ.) to get points of their preference judgements for ‘beauty’

Table 7. Regression (Manner I, Mountains).

Person	$R^2 (\hat{R}^2)$	F-r.	t_1-r.	t_2-r.	t_3-r.	t_4-r.
p.22	0.948 (0.879)	1.5	−0.8	0.1	0.1	−0.3
p.1	0.941 (0.862)	1.3	−1.6	0.6	−1.2	1.0
p.23	0.935 (0.849)	1.2	−0.4	−0.5	0.0	−0.7
Ave. of 42	0.926 (0.827)	1.0	−0.8	0.4	0.9	0.1
Significant	—	3p.s	2p.s	0p.	4p.s	1p.

Table 8. Regression (Manner I, Buildings).

Person	$R^2 (\hat{R}^2)$	F-r.	t_1-r.	t_2-r.	t_3-r.	t_4-r.
p.4	0.972 (0.934)	2.8	−0.8	0.6	0.0	−1.1
p.33	0.959 (0.904)	1.9	1.2	−0.1	0.7	0.5
p.22	0.899 (0.764)	0.7	0.9	1.1	−1.1	−1.0
Ave. of 42	0.621 (0.115)	0.1	−0.1	−0.1	0.5	−0.1
Significant	—	2p.s	2p.s	2p.s	3p.s	3p.s

Table 9. Regression (Manner II, Mountains).

Person	$R^2 (\hat{R}^2)$	F-r.	t_1-r.	t_2-r.	t_3-r.	t_4-r.
p.33	0.986 (0.967)	5.7	0.4	−4.0	−0.5	−1.7
p.15	0.970 (0.930)	2.7	0.8	−2.7	0.2	−1.2
Ave. of 42	0.493 (0.183)	0.1	−0.3	−0.2	0.0	0.1
Significant	—	2p.s	3p.s	4p.s	0p.	2p.s

Table 10. Regression (Manner II, Buildings).

Person	$R^2 (\hat{R}^2)$	F-r.	t_1-r.	t_2-r.	t_3-r.	t_4-r.
p.12	0.980 (0.954)	4.1	0.1	−3.3	−2.0	−1.0
Ave. of 42	0.905 (0.777)	0.8	−0.4	−0.6	0.1	−0.5
Significant	—	1p.	2p.s	2p.s	1p.	3p.s

of the 16 drawings in the previous section. We used 2 examination sheets; on the one, 8 drawings for bridges A~H with the background ‘Mountains’ (Figs. 1–8) are printed and on the other, 8 drawings for bridges A~H with the background ‘Buildings’ (for example: Fig. 9) are printed. Under the each drawing, 5-grade scales (‘not beautiful’ on the left edge, ‘ordinary’ on the middle and ‘beautiful’ on the right edge) are printed. The text on the top

Table 11. Stepwise (Manner I, Mountains).

Person	$R^2(\hat{R}^2)$	F-r.	t_1-r.	t_2-r.	t_3-r.	t_4-r.
p.23	0.871 (0.849)	2.9	—	—	—	–2.6
p.24	0.805 (0.726)	0.8	–1.0	—	1.1	—
p.42	0.777 (0.740)	1.5	–1.9	—	—	—
Ave. of 42	0.854 (0.795)	1.1	1.4	—	1.1	—
Significant	—	4p.s	7p.s	1p.	7p.s	2p.s

Table 12. Stepwise (Manner I, Buildings).

Person	$R^2(\hat{R}^2)$	F-r.	t_1-r.	t_2-r.	t_3-r.	t_4-r.
p.4	0.936 (0.910)	2.7	–1.9	—	—	–1.1
p.33	0.835 (0.808)	2.2	2.3	—		—
p.28	0.788 (0.753)	1.6	–1.9	—	—	—
Significant		6p.s	9p.s	0p.	1p.	4p.s

Table 13. Stepwise (Manner II, Mountains)

Person	$R^2(\hat{R}^2)$	F-r.	t_1-r.	t_2-r.	t_3-r.	t_4-r.
p.22	0.856 (0.832)	2.6	–2.4	—	—	—
p.15	0.831 (0.803)	2.2	—	–2.2	—	—
p.33	0.763 (0.723)	1.4	—	–1.8	—	—
Significant		4p.s	2p.s	6p.s	0p.	3p.s

Table 14. Stepwise (Manner II, Buildings).

Person	$R^2(\hat{R}^2)$	F-r.	t_1-r.	t_2-r.	t_3-r.	t_4-r.
p.28	0.836 (0.808)	2.2	–2.3	—	—	—
p.35	0.791 (0.756)	1.7	—	–1.9	—	—
p.42	0.758 (0.717)	1.4	–1.8	—	—	—
Significant		5p.s	7p.s	1p.	0p.	2p.s

of the sheets says, 'Judge beauty of the following drawings by 5 grades and mark it by your preference.' We divided the 42 examinees into 2 groups so that each group has 21 persons. Examinees in one group at first received only the examination sheet with the background 'Mountains' and marked it, while examinees in the other group at first received only the examination sheet with the background 'Buildings' and marked it. After that, examinees in the both groups then received another examination sheet respectively and marked it. We gave 5-grade points to the marked judgements (for example 1 point to 'not beautiful', 5 points to 'beautiful' and so on). We show the average judgement points which 42 examinees gave for the drawings and their deviations in Tables 5 and 6 in case of the backgrounds 'Mountains' and 'Buildings' respectively.

5. Regression Analyses

We carry out multiple regression analyses in 4 cases of 2 backgrounds 'Mountains'/ 'Buildings' and 2 Manners I/II regarding the preference judgement point of each examinee as a criterion variable y and also regarding the average judgement point of 42 examinees as y. The quantificational indices P_e, R_p, a and i are chosen as explanatory variables x_1, x_2, x_3 and x_4. Results of examinees for whom F-value (square of t-value) is over the 5% point, results for the average of all examinees and numbers of persons for whom each explanatory variable becomes statistically significant are shown in Tables 7–10 for the 4 cases, where R^2 is R-square; $\hat{R}^2$ is adjusted R-square; F-r. (F-ratio) is $F/F_{(0.05\%)}$; t_i is t-value for partial regression coefficients b_i of the regressed equation: $y = b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_0$; t_i-r. (t_i-ratio) is $t_i/t_{(0.025\%)}$. Regressed equations whose F-ratio is equal to or greater than 1 are statistically significant. Partial regression coefficients whose t_i-ratio is equal to or greater than 1 are statistically significant. Plus or minus of t_i-ratio corresponds to plus or minus of the partial regression coefficient and to its positive or negative correlation. Examinees of Person 1~Person 21 at first marked the examination sheet with the background 'Mountains', while examinees of Person 22~Person 42 at first marked that with the background 'Buildings'.

In any case the number of examinees who give a statistically significant result is at most 3 and the examinee who gives a significant result in a certain case does not always give significant results in other cases. There are examples in which no partial regression coefficients are statistically significant by t_i-ratio, although the regressed equations are significant by F-ratio (Table 7: Person 22). On the other hand there are examples in which most of regression coefficients are statistically significant by t_i-ratio, although the regressed equations are not significant by F-ratio (Table 8: Person 22). It depends on each case which partial regression coefficients among b_1~b_4 are statistically significant for many persons or not. For example, the regression analysis for case of Manner I with the background 'Mountains', b_2 (index R_p) is statistically significant for no persons, while b_3 (index a) is statistically significant for 4 persons (Table 7). On the other hand, the regression analysis for case of Manner II with the background 'Mountains', b_2 (index R_p) is statistically significant for 4 persons, while b_3 (index a) is statistically significant for no persons (Table 9). As for the regression analysis for the average judgement point of 42 examinees regarded as a criterion variable, only an analysis in case of the background 'Mountains' and Manner I is statistically significant by F-ratio.

Thus it is suggested that the 4 indices cannot well explain average preference of a certain group with not a small dispersion by person. If it is limited to analyses for each person, there are persons, for whom a regressed equation is statistically significant, although it depends on persons, Manners and Backgrounds which indices are more explainable for the person's preference.

Here in order to choose statistically significant explanatory variables avoiding multicollinearity from the 4 indices P_e, R_p, a and i, we try analyses by Stepwise Method. For 4 cases of 2 backgrounds 'Mountains'/'Buildings' and 2 Manners I/II, picking up more explainable indices as explanatory variables from the 4 indices, we carry out multiple regression analyses regarding the preference judgement point of each examinee as a criterion variable y and also regarding the average judgement point of 42 examinees as y. Results of 3 persons for whom highest R-square is given, a result for the average point of 42 examinees and numbers of persons for whom each explanatory variable is significant are shown in Tables 11–14 for the 4 cases. In half of the persons no indices are statistically significant, while in the other half persons one (or two in cases) index is significant. In all cases results of Stepwise Method give more number of persons for whom the regressed equation is statistically significant by F-ratio than results of the ordinary regression analyses. However persons with higher R-square in Stepwise Method are not always same as those in the ordinary regression analysis. In 3 cases except the case with Manner II and the background 'Mountains', number of persons for whom the index P_e is significant is 7~9 by Stepwise Method, while the number is 2~3 by the ordinary regression analysis.

In the analysis by Stepwise Method with Manner I and the background 'Mountains', the indices P_e and a are statistically significant for the average judgement point of 42 examinees. In that sense, it may be said that P_e and a in the case represent 'popularly common' preference of the examinees. It depends on persons which indices give statistically significant correlations. Furthermore the correlations are not always positive but also negative. For example, since values of P_e generally become small when up-and-downness of bridges becomes small (GOTOU *et al*., 1999), it may reflect difference of personal senses of value; some persons feel that bridges with small up-and-downness are 'beautiful' and the other persons feel that bridges with big up-and-downness are 'beautiful'. As Manner II does not always give higher correlations than Manner I, to increase extracted lines of bridges does not always make explanatory variables more explainable.

6. Concluding Remarks

We carried out multiple regression analyses for the preference judgement point of each examinee as a criterion variable using the indices quantified from contour lines of structural landscape drawings as explanatory variables. For half of the examinees one or two of the four quantificational indices proposed in this study give a statistically significant correlation with each person's preference for the landscapes. However, it depends on persons which indices give a statistically significant correlation. We did not find indices which give a enough significant correlation with the average judgement point of 42 examinees. On the other hand, some persons can give significant positive correlations for indices for which the other persons give significant negative correlations. It seems to be shown by the indices that two person's preference judgements can be quite opposite to each other by persons. In this study we showed possibility to regressionally estimate scenic preference of each person for landscapes, while we found that it is difficult to estimate averaged scenic preference of the group, each of whose members has different (quite opposite) preference to the others. Although we introduced a convolution between contour lines of a structure and of its background and quantified only spectrums of the convolution for a simple analysis, it might be more explainable approach to quantify spectrums of a structure and of its background respectively and then try to find relations between the respective quantified spectrums, which give statistical significance with scenic preference. How to find and/or quantify the relations is a subject for our future study.

REFERENCES

GOROMARU, H. and TERASAWA, T. (2001) Evaluation of the shape, the characteristics and the color of bridge landscapes, *Proc. 57th JSCE Annual Meeting*, I-B105 (in Japanese).

GOTOU, H., HIROSE, K., SUGAWARA, K. and IWAKUMA, T. (1999) Quantification of landscapes using convolution, *J. Structural Eng., JSCE*, **45A**, 605–614 (in Japanese).

HANDS, D. E. and BROWN, R. D. (2002) Enhancing visual preference of ecological rehabilitation sites, *Landscape and Urban Planning*, **58**, 57–70.

ISE, T. and IWAKUMA, T. (1994) A proposal on quantificational evaluation indices of structural landscapes, *Bull. Soc. Sci. Form, 'SYMPOSIUM FOR SCIENCE ON FORM'*, **9**, No. 2, 14–15 (in Japanese).

KALIDINDI, N., LE, A., PICONE, J., ZHENG, L., YAQUIN, H. and RUDIS, V. A. (1997) Scenic beauty estimation of forestry images, *Proceedings of the IEEE Southeastcon, Blacksburg, Virginia, USA*, pp. 337–339.

KAMEI, E. and TSUKIO, Y. (1992) A study on fluctuations of skyline and its impression of comfort, *J. Archit. Plann. Environ. Engng., AIJ*, No. 432, 105–111 (in Japanese).

STAMPS, A. E. (2002) Fractals, skylines, nature and beauty, *Landscape and Urban Planning*, **60**, 163–184.

SUGIYAMA, T., FUKASAWA, Y., TSUJI, K. and TAKAHASHI, Y. (1989) Quantitative estimation of aesthetics of landscape with bridge by psycho-vector, *J. Structural Eng., JSCE*, **35A**, 523–532 (in Japanese).

SUGIYAMA, T., FUKASAWA, Y., SHIMIZU, K., NAKAMURA, T. and TERANISHI, I. (1991) Quantitative estimation of aesthetics of landscape with bridge by psycho-vector based on weighted objective decision analysis, *J. Structural Eng., JSCE*, **37A**, 677–686 (in Japanese).

YASUDA, K., SHIRAKI, W., KAKUNO, D., DOGAKI, M. and ADACHI, M. (2001) A study on application of fractal dimension and scenery evaluation of girder bridge, *J. Structural Eng., JSCE*, **47A**, 327–334 (in Japanese).