Analysis of Feature Curves in Buddhist Statue Faces

Shin TSUCHIYA,† Takashi X. FUJISAWA,† Noriko NAGATA† and Shigeki KOBAYASHI‡
†: Kwansei Gakuin University, nagata@ksc.kwansei.ac.jp
‡: Keiso Research Laboratories, kobayashi@keisolabs.com

Abstract We propose a quantitative method of studying Buddhist statue faces, employing the logarithmic curvature radius. We select two curves, a lateral aspect curve and an eyebrow curve from Buddhist statue images. The curves are derived from grayscale images, and logarithmic curvature radiuses are derived from the curves. The logarithmic curvature radiuses are transformed into Z scores, and the curve is categorized using a hierarchical cluster analysis method. As a result, the statues were divided into three groups based on the lateral aspect curve and the eyebrow curve respectively, and it could be confirmed that each group represents the geometric character in the face of the statue. However, these groups could not be distinguished according to the region or period. In the future we plan to increase the number of statue images and the number of ethnic groups looked at.

1. Introduction

Statues of Buddha began to be made in India around 1st century B.C and then spread to other ethnic groups and royal palaces in various Asian countries [1], [2]. At the same time, the molding styles became diversified under the influence of each place and ethnic group. Figure 1 displays statues of Buddha and the people living the region where they were created. For example, it shows that the statue of Buddha in the vicinity of the Tarim basin resembles the Uzbeks living in the area.

There have been many studies of the style of Buddhist statues, however, they are based on an evaluation of the form subjectivity. We here propose a new quantitative method for studying Buddhist statue faces [3]-[5]. Sasaki et al. abstracted the parts of curves which corresponded to the eyebrow curves from the images of Buddha statue faces, and analyzed them using the slope, depth, and angle of eyebrow curve [3], [4]. Yamada et al. measured the faces of people and dolls in three dimensions of the faces of people and dolls, and analyzed the curvature radius of the cross section of the characteristic points of the faces, as the key lines which structure the curves of the face [6].

Although it is desirable to measure the faces of Buddha statues in three dimensions, it is very difficult to arrange in practice. In this study, we propose a quantitative method of studying the features of Buddhist statues, in which we analyze the characteristics of the curved lines of the Buddhist statue faces, employing the logarithmic curvature radius.

2. Analyzing the Characteristics Employing the Logarithmic Curvature Radius

2.1 Characteristic Curves

We select two characteristic curves for analysis. One is the lateral aspect curve from the hairline, artificial trichion, (tr-a) to the top of the nose-bridge, artificial pronasale (prn-a) and the other is the left eyebrow curve [7]. These characteristic curves are derived from grayscale images.

2.2 Abstract of Characteristic Curves

Regarding the profile curves, to abstract the curve from tr-a to prn-a, we binarize the grayscale images of the profile so that we can abstract the facial area and arranged the edge tracing. Regarding the left eyebrow curve, generally the eyebrow is not drawn on Buddha statues. Thus, we draw dots on the edge part corresponding to the eyebrow, and abstract an approximate curve by applying 3D spline interpolation.

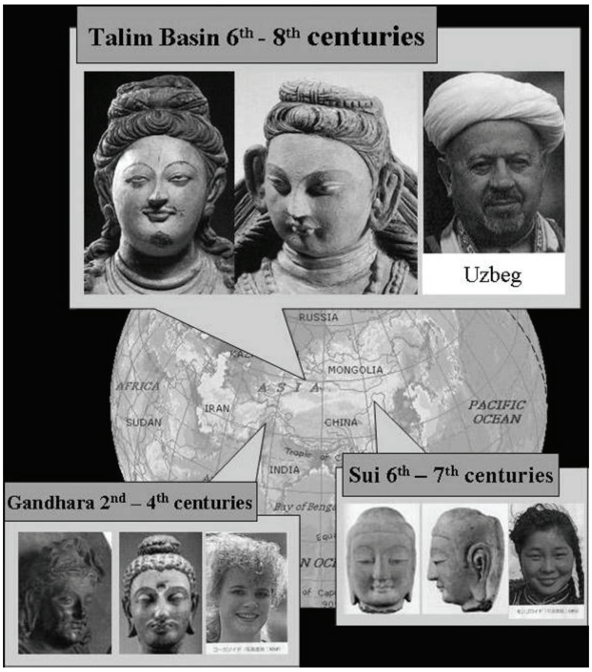


Fig. 1 The relationship between Buddha statues and people living in the region where they were created.

Fig. 2 Examples of a lateral aspect curve from artificial trichion (tr-a) to artificial pronasale (prn-a) of a profile image (left), and the left eyebrow curve of a full face (right).

2.3 Curvature Radius and Its Changes

We express x = x(t), y = y(t) employing parameter t for the path length against the obtained curve, then calculate the curvature radius ρ(t).

$$\rho(t) = \frac{(x'^2 + y'^2)^{\frac{3}{2}}}{x'y'' - y'x''} \qquad \dots (1)$$

Since it is difficult to obtain all the changes of curvature from the curvature radius data, the curvature radius is divided by total length of the curves. Then the logarithmic curvature radius (LCR) C_i is calculated by taking the logarithms below.

$$C_i = \begin{cases} 10\log(\frac{|\rho_i|}{S}) & (\rho_i \geq 0) \\ -10\log(\frac{|\rho_i|}{S}) & (\rho_i < 0) \end{cases} \qquad \dots (2)$$

P_i : curvature radius

S : length

There are 180 LCR data points in both the lateral aspect curve and the eyebrow curve.

2.4 Hierarchical Cluster Analysis

The hierarchical cluster analysis is determined by changing from the logarithmic curvature radius obtained to Z [9].

$$Z_i = \frac{C_i - \mu}{\sigma} \qquad \dots (3)$$

C_i : logarithmic curvature radius (LCR)

μ : average

σ : standard deviation

3. Results of Analysis

We analyzed images of Buddha statues in China and Japan (Oumi prefecture).

We derived the logarithmic curvature radius for the Lateral aspect curve from tr-a to prn-a from forty-nine images of Buddha statues which were selected at random, and the hierarchical cluster analysis was done.

Table. 1 Results of hierarchical cluster analysis of the lateral aspect curve from tr-a to prn-a (49 Buddha statues, 29 Japanese and 20 Chinese)

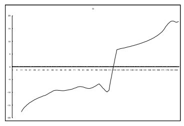
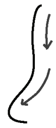
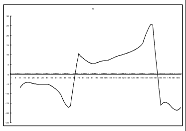
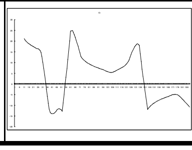
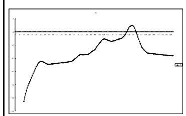
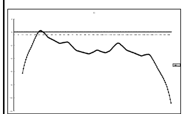
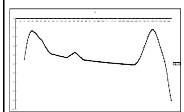
Cluster	Japan	China	total	Buddha statues	LCR C_i	Features
1	16	6	22			
2	6	12	18			
3	7	2	9			
total	29	20	49			

Table. 2 Results of hierarchical cluster analysis of the eyebrow curve (42 Buddha statues, 29 Japanese and 13 Chinese)

Cluster	Japan	China	total	Buddha statues	LCR C_i	Features
1	8	10	18			
2	11	1	12			
3	10	2	12			
Total	29	13	42			

As a result they were divided into three groups with the characteristics shown in Table 1. If the LCR is positive, the curve is concave, on the other hand, if it is negative, the curve is convex.

Regarding the eyebrow curve, forty-two images of Buddha statues selected at random were analyzed in a similar way. As a result, they were divided into three groups with the characteristics shown in Table 2.

4. Discussion

Regarding the lateral aspect curve from tr-a to prn-a, the characteristics of the curve of cluster one are convex → concave, cluster two, convex → concave → convex, and cluster three, concave → convex → concave → convex. Cluster one includes most Buddha statues with a Grecian nose, and its lateral aspect curve from the artificial sellion (se-a) to prn-a is rectilinear. Cluster two includes many Buddha statues with a lateral aspect curve from se-a to prn-a and their brows are rounded. Cluster three includes most

Buddha statues whose brows are concave → convex.

Next, regarding the eyebrow curve, three clusters were classified according to the growth of the curvature. That is to say, where the curvature of the eyebrow curve grows at the outer side, it is placed into cluster one. When the curvatures grow at the inner side it is placed into cluster two, and when the curvatures grow at the inner and outer sides it is placed into cluster three. Regarding Chinese Buddha statues, there is a tendency for the curvatures of most of the eyebrow curves to grow at the outer side.

In this way, by employing the logarithmic curvature radius, we could analyze the lateral aspect curve from tr-a to prn-a and the characteristics of the eyebrow curve. In the future, we will increase the number of images of Buddha statues, and will classify the type of Buddha statues and the places where the statues were made. At the same time, we will analyze in an integrated method by increasing the amount of character curves.

5. Conclusion

By employing the logarithmic curvature radius, we could implement a quantitative observational study of the lateral aspect curve from tr-a to prn-a and the eyebrow curve. Also, we could break down the Buddha statues according to their characteristics. However we could not get a synthetic interpretation of the two characteristic curves.

In the future, we will increase the number of images of Buddha statues and the number of the characteristic curves so that we will be able to analyze in an integrated way.

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Tsuchiya, Shin: is currently a fourth year B.S. student in Informatics course, Kwansei Gakuin University. His interests include affective computing and media processing.

Fujisawa, Takashi X.: received the M.S. and Ph.D. degrees from the Graduate School of Informatics, Kansai University, Japan, in 2001 and 2004, respectively. He is currently a Postdoctoral Fellow at the Reseach Center for Human Media in Kwansei Gakuin University, Japan. His research interests include face recognition and music perception.

Nagata, Noriko: received the B.S. degree in mathematics from Kyoto University in 1983 and the Ph.D degree in systems engineering from Osaka University in 1996. In 1983, she joined the Industrial Electronics and Systems Laboratory, Mitsubishi Electric Corporation, where she was involved in the application of machine vision technology. Since 2003, she has been an associate professor of the Department of Informatics in Kwansei Gakuin University. Her research interests include affective computing and multimedia engineering.

Kobayashi, Shigeki: received the B.S. degree in biology in 1962 and the Ph.D degree in 1971 in biological engineering both from University of Tokyo. He joined the R & D Labs, Omron Corporation in 1962 and then shifted to Omron Institute of Life Science as Director. He developed machine vision systems such as a morphological blood cell classifier and AOI systems of factory automation. In 1995, he established Keiso Research Labs and now conducts research in artificial form.