Development of Computer Vision System to Extract *Kansei* Information from Facial Expressions

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Abstract

In the Japanese language, the word “*Kansei*” is used to indicate mental states or activities that occur in response to stimulation from the outside world. For example, emotion is defined as a component of *Kansei*. In the West, words such as sensibility and perceptiveness are often used with meanings similar to *Kansei*. Furthermore, in the Japanese field of *Kansei* engineering, designers strive to integrate human feelings and sensibilities more closely with manufacturing and production activities. Accordingly, if *Kansei*-related information can be extracted in various situations, it is believed that distinctive design, development, and evaluation processes become possible. In this paper, we describe the fabrication of an inexpensive and near real-time system capable of extracting *Kansei* information from user facial expressions. To accomplish this, we developed a computer vision system using the free OpenCV image-processing library. The characteristic values calculated from these inputs were the variation (the normalized polygon area change ratio) of four items: the inner end of the eyebrows, the upper and lower parts of the eyes, and the corners of the mouth, which were then calculated using seven face nodes. Three *Kansei* information types were targeted: positive *Kansei* information (appreciation, fun, and happiness), negative *Kansei* information (unpleasantness and distaste), and *Kansei* information associated with shock or surprise. With the assistance of 12 test subjects, we began working to obtain specific *Kansei* knowledge, and quickly determined that the relationships between facial expressions and *Kansei* information were highly individual in nature. Therefore, in the next stage, we formulated an algorithm to discriminate the three *Kansei* information types while focusing on a single subject, and obtained good results. However, since facial reactions vary significantly between individual human beings, it is currently necessary to prepare a seven-point template image in advance for each person to be examined, and then to adjust the algorithm parameters after measuring their facial expressions in order to obtain *Kansei* information. Despite these initial difficulties, our results show that an inexpensive and near real-time computer vision system capable of extracting facial expression *Kansei* information can be constructed. We believe that such systems can make it possible to apply *Kansei* information decision support to a variety of automatic evaluation and design processes.

Keywords

Kansei, computer vision, automatic evaluation and design, decision support system, Open CV

Introduction

In the Japanese language, the word “*Kansei*” is used to indicate mental states or activities that occur in response to stimulation from the outside world. For example, emotion is defined as a component of *Kansei*. In the West, words such as sensibility and perceptiveness are used with meanings similar to *Kansei*.

In this study, we aim to apply *Kansei* engineering, which is a field in which *Kansei* information and human imagery are adapted to physical design elements in order to create products, environments, food, and services that are compatible with *Kansei*. By utilizing *Kansei* information, we believe that the following will become possible:

- Design, development and evaluation of new agricultural products and foods with colors, shapes, scents, etc., that evoke strong consumer approval;
- Development of unique marketing methods; design and

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evaluation of office and living spaces that incorporate green amenities (Asaumi et al. 1995);

- Landscape creation and evaluation for cities, farming villages and gardens, with comfort and healing effects;
- Development of agricultural machines with an appearance, or level of comfort, that evokes strong consumer approval;
- Development of agri-robots capable of *Kansei* communication (Sasaki 2011);
- Welfare and nursing support using animals, plants and/or artificial life.

In this study, two specific application examples are considered (Fig. 1). The first example relates to the disaster reconstruction program in Fukushima Prefecture and corresponding efforts by the Tokyo University of Agriculture to create a Cyber field simulation system that can be used for restoration of farming and mountain villages in disaster areas. This effort consists of building a base simulation system by adding geographic information system (GIS) map information and three-dimensional (3D) space information obtained using a mobile mapping system. It was designed for the restoration of farming and mountain villages, and can be used to construct a regional model simulator that gives consideration to disaster prevention and post-reconstruction landscaping. If *Kansei* information can be utilized, this can be expected to lead to the creation of a landscape simulator. In other words, if *Kansei* information proves to be useful, it may be possible to automatically design landscapes that “heal” inhabitants, or make them feel more positive, when redeveloping rural settlements after earthquakes or other disasters. Mobile mapping is the process of collecting geospatial data from vehicles equipped with remote sensing systems. The second example in the present paper is the development of an educational application related to food and the environment

for tablet personal computers (PCs). Until recently, the effects of a variety of education programs and efforts could only be evaluated through questionnaire surveys and similar methods. However, when *Kansei* information such as the degree to which students feel interested (e.g., whether they feel bored or stimulated) can be obtained, it can be used for the evaluation of educational applications and software, and other education related improvements.

As described above, this section of the study focuses, in particular, on the fabrication of an inexpensive and near real-time system to extract *Kansei* information from the facial expressions of a test subject via computer vision, and the related obtained *Kansei* knowledge, which was then used to create a discriminatory algorithm for discerning facial expressions.

The present study has the following goals:

1. Determine the relationship between facial expression and *Kansei* information for multiple subjects;
2. Develop a computer vision system capable of near real-time identification of *Kansei* information based facial expressions.

It is said that 55% of all emotional indicators, which are a part of *Kansei* information, can be presented by facial expressions (Mehrabian 1986). Accordingly, in the present study, we focus on facial expression information because of its importance in presenting emotional context, and because a facial expression recognition system can be easily achieved using a camera and image processing software, without requiring special sensors. Additionally, facial expressions can be measured without contact and can be easily used as feedback information. By developing the system further, we believe that *Kansei* information at the unconscious level, which cannot be captured through questionnaire surveys, can also be obtained.

Fig. 1 Image of *Kansei* application

In our earlier studies (Sasaki et al. 2007, 2009), nodes were placed on the faces of test subjects and their movements were tracked. However, that system required physical contact and was expensive. Another related study extracted *Kansei* information from facial expressions (Zisheng et al. 2010), but it could not operate in real time. In fact, a number of studies aimed at more fully grasping *Kansei* information have been carried out (e.g., Fujimura 2008).

However, no inexpensive camera-based computer vision system for obtaining near real-time *Kansei* information has been developed to date. Therefore, if such a system could be developed, it would be superior in terms of speed and cost effectiveness, and could be applied in food and environmental fields.

Development System and *Kansei* Extraction Method

Based on the results of our earlier study (Sasaki et al. 2007) and other related studies, it is known that people tend to express *Kansei* information using their eyes and mouth. Based on the facial graph created by Ayinde and Yang (2002), in order to obtain *Kansei* information, a total of seven facial nodes must be used. These are the inner ends of the eyebrows, the inner corners of the eyes, the outer corners of the eyes, the upper eyelids, the lower eyelids, and both corners of the mouth. Fig. 2 shows these seven facial nodes on the developed computer vision system. The node positions are determined using a template matching technique that searches for a partial image signal (target) in the image that corresponds to a known template signal. The position of an object is detected by first storing a region of the object to be traced in each image of a video as a template image, and then detecting a region that has a high degree of similarity to the template image in a time-series manner. The template used was a 19×19 pixel image. The seven facial nodes

were then connected, which permitted the creation of four polygons corresponding to the inner end of the eyebrows (three facial nodes: inner end of the eyebrow, inner corner of the eyes, and outer corner of the eyes), the upper (three facial nodes: inner corner of the eyes, outer corner of the eyes, and upper eyelids) and lower parts of the eyes (three facial nodes: inner corner of the eyes, outer corner of the eyes, and lower eyelids), and the corners of the mouth (three facial nodes: inner corner of the eyes and both corners of the mouth), as shown in Fig. 3. These seven points were chosen because *Kansei* information is readily visible in the eyes and mouth of human subjects, and thus allows us to raise the processing speed. In this study, we used the Windows 7 operating system, the free OpenCV image-processing library, and Visual Studio 2010 for software development. We used OpenCV 2.3.1 (iostream library) for camera image acquisition and identification of the pattern matching characteristics/amounts. Using a common PC (Vostro 3550, Dell Inc., Intel Core i3 2350M, memory size: 4 GB, ATI HD Switchable Graphics) with a built-in Web camera, 640×480 pixel images were acquired. The distance between the camera and the subject was generally 50 cm; it was found that facial nodes could be correctly traced for distances of 20 to 60 cm. In order to increase the probability of proper facial node recognition, subjects did not wear glasses in this study.

The polygon areas were then calculated and extraction of *Kansei* information was attempted. In this paper, $N(i)$ is defined as a facial node and the following definitions are used: $N(1)$ indicates the inner end of the eyebrow, $N(2)$ indicates the upper eyelid, $N(3)$ indicates the lower eyelid, $N(4)$ indicates the inner corner of the eye, $N(5)$ indicates the outer corner of the eye, $N(6)$ indicates the left corner of the mouth, and $N(7)$ indicates the right corner of the mouth. The parameters used for facial expression analysis were the normalized polygon area change

Fig. 2 7 face nodes for polygon areas

ratio $\Delta A(i, j, k)$, as calculated using the following equation:

$$\Delta A(i, j, k) = 100 \cdot \frac{A_{tk}(i, j, k) / scale^2 - A_{t0}(i, j, k)}{A_{t0}(i, j, k)} \quad (1)$$

where

$$scale = L_{tk}(4, 5) / L_{t0}(4, 5), \quad (2)$$

which allows efficient evaluation of the back and forth head movements of each subject in the direction towards the camera (zoom in/out), as follows:

$$A_t(i, j, k) = \frac{1}{2} \cdot \left| \begin{aligned} & \{x_t(i) \cdot y_t(j) - x_t(j) \cdot y_t(i)\} \\ & + \{x_t(j) \cdot y_t(k) - x_t(k) \cdot y_t(j)\} \\ & + \{x_t(k) \cdot y_t(i) - x_t(i) \cdot y_t(k)\} \end{aligned} \right| \quad (3)$$

Hereafter, ΔA is defined as the normalized polygon area change ratio, t is the time (tk : time of *Kansei* facial expression, $t0$: time of normal facial expression), i, j , and k are node numbers, $x_t(i)$ and $y_t(i)$ are the x and y coordinates, respectively, of $N(i)$ at time t , $L_t(i, j)$ is the distance between $N(i)$ and $N(j)$ at time t , $scale$ indicates the scale ratio for normalization at times tk and $t0$, and $A_t(i, j, k)$ is the area of the polygon (triangle) formed by $N(i)-N(j)-N(k)$ at time t . The ΔA values were calculated for the four polygons at the inner ends of the eyebrows, upper parts of the eyes, lower parts of the eyes, and corners of the mouth. Since one of the goals of this study was to evaluate the possibility of using *Kansei* information to create pleasing products and environments, we focused on facial expressions associated with positive *Kansei* information (fondness, enjoyment, happiness, and pleasure), negative *Kansei* information (distaste, sadness, and unpleasantness), and surprise *Kansei*

information.

The following experimental method was used. After the purpose of the experiments, the experimental procedure and the precautions taken, were explained to the test subjects, they were asked to provide written informed consent and give their ages and genders. They were then given an overview of the contents of the target *Kansei* expressions and instructed to practice those expressions using a mirror, after which the experiments to obtain *Kansei* expression information were conducted. Although the test subjects made their *Kansei* expressions intentionally, they were asked to make them as naturally as possible. The test subjects were 12 men (ages: 18–22). For these 12 persons, 50 data images were acquired for each normal, positive, negative, and surprise *Kansei* expression (2,400 images in total). ΔA values were then computed from the image data node changes for each *Kansei* expression using the mean node locations for 50 normal images. There were only slight variations between the 50 normal images.

Results and Discussion

Knowledge about *Kansei* obtained from multiple persons

After confirming that changes in *Kansei* information could be recognized by our current system in the preliminary experiments, we then used the system to obtain this information from each of the 12 test subjects. Fig. 4 shows the obtained positive, negative, and surprise *Kansei* information, as well as an example of the program execution results, and Fig. 5 shows the data for the 12 subjects. In Fig. 5, the x-axis shows the subject number and the y-axis shows the change rate. In addition, Fig. 5(a) shows positive *Kansei* information, Fig. 5(b) shows negative *Kansei* information, and Fig. 5(c) shows surprise *Kansei* information. From the results of the four polygons created using

Fig. 3 4 polygons for *Kansei* extraction

rectangles to connect the face nodes, and by connecting the polygons with lines, changes in the absolute values of ΔA were determined, and are listed in Table 1. We found that the direction of the four polygons accompanying an expression alteration varied between the individual test subjects. In order to consider which areas should be focused on, based on their size and direction, the absolute variations were calculated (Table 1). Moreover, in order to investigate what trends accompany direction variations when multiple persons are considered, the poly-

Table 1 Absolute value changes of each *polygon area** (%)

	positive <i>Kansei</i>	negative <i>Kansei</i>	surprise <i>Kansei</i>
Inner end of the eyebrows	15.3±11.7	12.9±7.8	14.6±11.8
Upper part of the eyes	18.4±13.9	13.7±9.9	15.1±9.9
Lower part of the eyes	18.4±19.3	15.7±10.4	14.6±12.3
Corners of the mouth	28.8±15.7	11.8±5.7	17.9±12.8

* average ± standard deviation

Table 2 Subject percentage about the change direction (positive *Kansei*)

	Plus (%)	Minus (%)
Inner end of the eyebrows	50.0	50.0
Upper part of the eyes	41.7	58.3
Lower part of the eyes	25.0	75.0
Corners of the mouth	83.3	16.7

Table 3 Subject percentage about the change direction (negative *Kansei*)

	Plus (%)	Minus (%)
Inner end of the eyebrows	16.7	83.3
Upper part of the eyes	25.0	75.0
Lower part of the eyes	8.3	91.7
Corners of the mouth	33.3	66.7

Table 4 Subject percentage about the change direction (surprise *Kansei*)

	Plus (%)	Minus (%)
Inner end of the eyebrows	91.7	8.3
Upper part of the eyes	58.3	41.7
Lower part of the eyes	58.3	41.7
Corners of the mouth	75.0	25.0

gon variation percentages were summarized, as shown in Tables 2–4.

As can be seen in Table 1, the results confirm that changes can be identified, and that the constructed system can be useful. Information obtained from multiple persons is next examined. For positive *Kansei* information, the changes in ΔA were

(a) positive *Kansei*

(b) negative *Kansei*

(c) surprise *Kansei*.

Fig. 4 Examples of the acquired images

(a) positive Kansei

(b) negative Kansei

(c) surprise Kansei

Fig. 5 12 subjects data about change rate of polygon area

approximately 15–29%, and the changes at the corners of the mouth were about 29%, which was notably higher than the others. For negative *Kansei* information, the changes were about 11–16%, with the change at the lower parts of the eye (approximately 16%) found to be slightly higher than that for the other nodes. For the surprise *Kansei* information, the changes were about 15–18%, with the change at the corners of the mouth slightly higher than that for the other nodes.

In the next stage of our investigation, a result was counted as positive if the normalized polygon area change ratio increased and as negative if it decreased, after which the ratios of the corresponding test subjects were checked. These results are shown in Tables 2–4. As a general trend, it was found that, for positive *Kansei*, the change in ΔA for the inner end of the eyebrow and the upper parts of the eyes depended on the subjects, whereas that for the lower parts of the eyes always decreased, and that for the corners of the mouth always increased. For negative *Kansei* information, all normalized polygon area change ratios showed a decreasing trend, which was notably stronger at the inner end of the eyebrow and lower parts of the eyes. For surprise *Kansei* information, the ΔA values showed an increasing trend as a whole, which was stronger at the inner end of the eyebrow in particular.

Based on the above results, since the direction and amount of the change in ΔA depend on the individual, we believe a general trend can be speculated. However, it is thought that the *Kansei* information changes must be discerned individually. For discerning the three types of *Kansei* information from the results for the multiple test subjects in this study (positive *Kansei* information: minus at the lower parts of the eyes and plus at the corners of the mouth; negative *Kansei* information: minus at both the inner end of the eyebrow and lower part of the eyes; and surprise *Kansei* information: plus at both the inner end of the eyebrow and the corners of the mouth), it is thought that focusing on the directions and amounts is informative.

Building and evaluation of *Kansei* discrimination algorithm

Next, selecting a single test subject that had not participated in the earlier experiments, we examined the possibility of distinguishing each of the three targeted *Kansei* information types. It was decided to focus on a single test subject because, as previously mentioned, the directions and amounts of *Kansei* information change varies from individual to individual. Using this test subject, we then built an algorithm capable of identifying *Kansei* information from facial expressions. The average values and standard deviations of ΔA for the selected female test subject are shown in Table 5 (10 data points for each *Kansei* information type). The sizes of the changes for this subject were small overall.

Here, in order to determine which index is suitable from the

four characteristic quantities, a distinction index formulated in a previous study (*D.I.*, Sasaki et al. 2000) was calculated (Table 6). *D.I.* is a simplified index used when considering variations between categories (Eq. (4)).

$$D.I. = \frac{|\mu_{\omega_1,x} - \mu_{\omega_2,x}|}{\sqrt{\sigma_{\omega_1,x}^2 + \sigma_{\omega_2,x}^2}} \quad (4)$$

Here, $\mu_{\omega_1,x}$ and $\sigma_{\omega_1,x}^2$ are the average and the variance for each category, respectively. In general, discrimination is easy when the *D.I.* is high. Reviewing the results shown in Table 6, it can be seen that the information about the corners of the mouth is most suitable for discriminating between positive and negative *Kansei* information, that the upper parts of the eyes are suitable for discriminating between the positive and surprise *Kansei* information, and that the corners of the mouth are suitable for discriminating between negative and surprise *Kansei* information.

In the next stage, we applied the holdout method (H-method) to determine error rates. The H-method is a cross-calibrated division learning technique used to determine error rates by interchanging the learning sample with the test sample. Using this method, the obtained samples were randomly divided into learning and test sample categories, which were then evaluated. This operation was repeated 1,000 times to calculate an average value, which was considered to be the error rate. The results of this process are shown in Table 7. These results showed that discrimination between positive and negative *Kansei* information and between negative and surprise *Kansei* information was

Table 5 Normalized polygon area change ratios* (%)

	positive <i>Kansei</i>	negative <i>Kansei</i>	surprise <i>Kansei</i>
Inner end of the eyebrows	0.05±2.47	-18.80±2.70	0.75±2.92
Upper part of the eyes	6.07±4.27	-15.08±6.65	-0.42±3.75
Lower part of the eyes	3.35±3.36	-21.71±8.96	2.28±3.57
Corners of the mouth	2.69±1.34	-10.81±1.03	1.76±1.26

* average ± standard deviation

Table 6 *D.I.* compare of each polygon area

<i>D.I.</i>	inner end of the eyebrow	upper parts of the eyes	lower parts of the eyes	corners of the mouth
positive–negative	5.15	2.68	2.62	8.00
positive–surprise	0.18	1.14	0.22	0.51
negative–surprise	4.91	1.92	2.49	7.72

Table 7 H-method identification result compare

<i>Kansei</i>	information	The H-method misconception percentage* (%)	optimal threshold
positive–negative	corners of the mouth	0.2±2.6	–4.95%
positive–surprise	upper parts of the eyes	21.1±13.5	2.6%
negative–surprise	corners of the mouth	0.0±0.0	–5.2%

* average ± standard deviation

possible at a rate of nearly 100% using the information obtained from the corners of the mouth. For positive and surprise *Kansei* information, an 80% discrimination rate could be achieved from the information of the upper parts of the eyes. The optimal threshold values for those discriminations were obtained statistically, and the three types of *Kansei* information for the target test subject could be identified using the algorithm discussed below.

In this system, it was first necessary to separately obtain learning data relating to facial expression *Kansei* information and to construct discrimination parameters and algorithms. Since the area where *Kansei* information tends to appear and the required identification precision vary between individual test subjects, this process will need to be automated in the future. Additionally, since we used general-purpose PCs equipped with built-in cameras in this study, we experienced a time lag of approximately two seconds when making determinations. In order to reduce this time lag, it will be necessary to consider using a computer and camera with higher specifications and avoid displaying the facial images and face nodes. Furthermore, while we computed the area change proportion of four normalized polygons in this study, it is highly likely that it will be possible to reduce the number of discrimination parameters for individual test subjects in the future, as well as to make real-time performance improvements by reducing the number of facial nodes and normalized polygon areas.

Concluding Remarks

In the first part of this study, a system that is capable of capturing and recognizing facial expressions using computer imagery was constructed. Based on an investigation involving multiple test subjects, the following results were obtained:

- For the three targeted *Kansei* information types, changes could be identified based on four specified normalized polygon area change ratios.
- For positive *Kansei* information, the changes at the corners of

the mouth were noticeably higher than those at the other nodes. For negative *Kansei* information, the changes at the lower parts of the eyes were slightly higher than those at the other nodes. For surprise *Kansei* information, the changes at the corners of the mouth were slightly higher than those at the other nodes.

- Regarding the directions of the changes as a general trend, it was found that, for the positive *Kansei* information, the change in ΔA for the inner ends of the eyebrows and upper parts of the eyes depended on the test subjects, whereas that for the lower parts of the eyes always decreased, and that for the corners of the mouth always increased.
- For negative *Kansei* information, all ΔA measurements showed a decreasing trend, which was notably stronger at the inner ends of the eyebrows and lower parts of the eyes.
- For surprise *Kansei* information, ΔA measurements showed an increasing trend as a whole, which was notably stronger at the inner ends of the eyebrows.

In the second part of this study, we explored the responses of a single test subject to determine the relationship between facial expressions and *Kansei* information, and then formulated an algorithm based on the results. A single test subject was used in this phase because the directions and amounts of the change related to *Kansei* information vary from individual to individual.

- When discriminating between positive and negative *Kansei* information, and between negative and surprise *Kansei* information, discrimination rates near 100% were found to be possible from the information obtained from the corners of the mouth.
- For discrimination between positive and surprise *Kansei* information, a discrimination rate of approximately 80% was found possible using information obtained from the upper parts of the eyes.

Thus, although it is currently necessary to prepare an individual template image for the seven points of each test subject in advance and to adjust the parameters after measuring the *Kansei*-related facial expressions, it is clear that inexpensive and near real-time computer vision systems capable of extracting facial expression *Kansei* information can be built. We believe that such systems have potential applications in automatic evaluation and design through decision support using *Kansei* information. Our future challenges include reduction of the amount of processing required for creating template images, as well as that for other processes, and the construction of a real-time *Kansei*-related facial information recognition system.

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