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<Survey> New Kansei Machine Vision Application
- A Prospect for Human Sensory Factors in Machine Vision -

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Abstract

This paper describes the trends of the Kansei machine vision technology. This technology is expected to be a breakthrough, answering new machine vision needs such as simulating human vision, monitoring human beings and human-machine interfaces. The paper presents its application fields, technical topics and various approaches including a facial caricaturing system and a pearl-quality evaluation system.

1. Introduction

Machine vision technology has gained wide popularity as a technique for automating operations conventionally dependent on the human eye, due to the diversification of production process and the increase of added-value products. The need for machine vision has also rapidly increased also in non-industrial fields such as medical science, cosmetics and securities. Further, with the diffusion of new technologies such as human-machine interface, multimedia, and virtual reality, machine vision technology is increasingly attracting attention as an important medium for visual information between man and machines.

One of the largest problems in machine vision technology is how to treat the feelings (subjectivity and intuition) inherent in vision, for instance, the extremely vague and non-quantitative information regarding the quality or finishing of a product, and the taste of consumers. Such information is called "kansei" in Japanese, inferring human sensory factors. It can also explained in English as follows [1]. A person observes and feels through the five basic senses - sight, hearing, smell, touch, and taste - and in the process, personal values, aesthetics and emotions seem to work in an interrelated and integrated manner. This we can refer to as "total sensitivity" or "receptiveness" and can better be expressed by the Japanese term "Kansei". "Kansei" is a more sophisticated sensual function than simply the feelings or senses. The word is, therefore, a subjective concept that runs counter to knowledge. In recent years, the "Kansei Engineering" [2] and "Kansei Information Processing" [3] have attracted attention as new approaches to the handling of sensitivity/ sensibility.

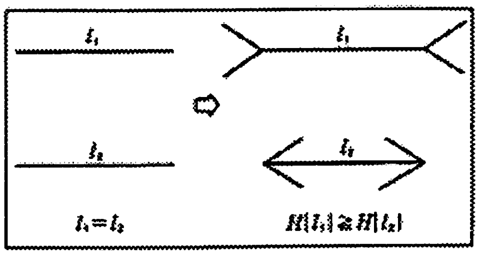
This paper describes the trends, topics and new approaches to machine vision technology where Kansei is introduced as a new paradigm [4], [5], [6].

2. Overview of Kansei Machine Vision

2.1 Problems of Kansei Machine Vision

Since the purpose of machine vision technology is to let machines work like the "human eye", it necessarily involves feeling and sensibility, and in fact efforts have been made for some time to carry out quantitative analysis of human feeling in sensory tests [7]. However, it is only in recent years that Kansei machine vision has attracted attention, providing an opportunity to reflect upon sensibility from the engineering standpoint [8].

One of the typical examples of kansei in machine vision is the well-known visual illusion as shown in Fig. 1. In this example, the straight lines with the same physical length appear to have different lengths depending on the length and angle of the added lines. The Kansei approach requires the creation of a model which can see this figure as the human eye does, and when applied to a machine, report that the lines are of different lengths.



(Muller-Lyer Illusion)

Fig. 1. Visual illusion and Kansei machine vision.

2.2 Application Fields of Kansei Machine Vision

The application fields of kansei machine vision and their examples are summed up in Table 1. Kansei machine vision technology is being used in different industrial fields such as steel-making, automobile, the chemical industry, the food industry, office appliances, and other industries. These applications can be broadly divided into the three types given below.

2.2.1 Kansei machine vision simulating human vision

Various kansei approaches have been tried in sensory tests even in conventional industrial fields for a long time. For example, various sensory evaluations have become compulsory for the inspection of paint quality in the machine and automobile industries. The technology has been introduced with great success in steel-making and metal-making industries for the evaluation of flaws and surface properties, in the chemical and textile industries for the inspection of chemicals [9] and fabrics [10], in the electrical and electronics industries for CRT inspections and for LED emission tests [11]. The inspection of printed materials has long been a subject of research for sensory tests, and the demands for quality evaluation regarding delicate color tones have become more and more severe. The sensory tests conducted on production lines are required to measure such vague items as luster, quality, and texture. And therefore it is still a problem how to duplicate the high-resolution and multi-dimensional visual function of human experts.

On the other hand, machine vision technology has recently made its way into fields beyond factories [12], [13], for example the inspection of cosmetics and jewelry [14], here the technology is required to evaluate, taking the side of the consumer instead of the maker. It has, therefore, become important to be able to understand users' tastes.

Table 1 Examples of Kansei Machine Vision Applications

Field	Application
Steel-making/metal-making	Evaluation of flaws and surface properties
Chemical industry/textiles	Inspection of chemicals and fabrics
Automobile	Visibility measurement
Electrical industry/electronics	CRT inspections/LED emission tests/ defect detection in ferrite cores
Electric and nuclear power	Surveillance systems
Food industry/agriculture/fisheries	Evaluation of luster, quality, and texture
Transportation/traffic	Detecting dozing drivers
Printing	Inspection of printed materials
Medicine	Surgical simulation
Cosmetics/jewelry	Skin evaluation, pearl appraisal
Architecture	Visualization of sights and buildings
Security system	Detecting intruders in surveillance systems/ identity authentication/face and fingerprint recognition
Office appliances	Image retrieval/color image scale
Home electronics	Virtual kitchen system

2.2.2 Kansei machine vision for monitoring human beings

In recent years there has been an increasing need to check the actions and expressions of human beings, such as detecting intruders in surveillance systems [15] or detecting dozing drivers [16]. Further, for individual authentication [17] in security systems, advanced machine vision technology is demanded to allow the maximum possible recognition performance, corresponding to human vision, for face and fingerprint recognition. How to model a human has therefore become an important problem.

2.2.3 Kansei machine vision for human-machine interfaces

Machine vision in human/machine information transmission, represented by keywords such as computer assistance, human-machine interface, communication, and media is also a new trend. Processing incorporating physiological visual characteristics is required in human support systems such as image retrieval using kansei information in image databases [18], and correcting age differences and visual characteristics [19]. Surgical simulation using CG [20] in medicine has great future prospects. Further, the transmission of kansei through facial expressions is attracting attention to "Face Engineering" which has gained popularity in recent years. The study of portrait making [21] is also an interesting approach in view of the overall research of "Face Engineering," and in such research how to make a machine with a kansei-like sense is a problem.

3. Approach to Kansei Machine Vision

There are different approaches to kansei machine vision technology in such fields as physiology, psychology, and information engineering.

3.1 Psychological approach and multivariate analysis

In this method evaluation data regarding human visual characteristics and sensory information is obtained and gathered through psychological experiments using the SD (semantic differential) method and the sensory factors are extracted by using multivariate analysis such as multidimensional scaling, and multiple regression analysis [22]. For example, the inspectors are asked to evaluate a certain object in 5 - 7 stages by each of several selected preset pairs of adjectives such as "bright-dark." Through the relationship between the data thus obtained and the actual physical properties of the object, the measured values of the object are obtained to allow conversion into kansei information. This method has long been systematized in sensory tests as a basic method, and is still being widely used.

The color image scale [23], a means devised for systematic representation of kansei information in color, is a precise example of this research. Figure 2 shows the color combination image scale. Here, the color image is expressed by using adjectives, and is classified into a two-dimensional space with two axes, warm-cool and soft-hard on a coordinate plane, plotted to allow a color arrangement which exactly matches the linguistic sense. There are other examples of these applications such as representing turbidity which composed of two factors: particle diameter and lightness.

This method, however, is used under the presumption that the model is a linear one, so that a more flexible method is desirable for a non-linear concept like kansei. Further, the black box between the measured value and the kansei data makes it difficult to clarify the relation between the two, which is a shortcoming of this method.

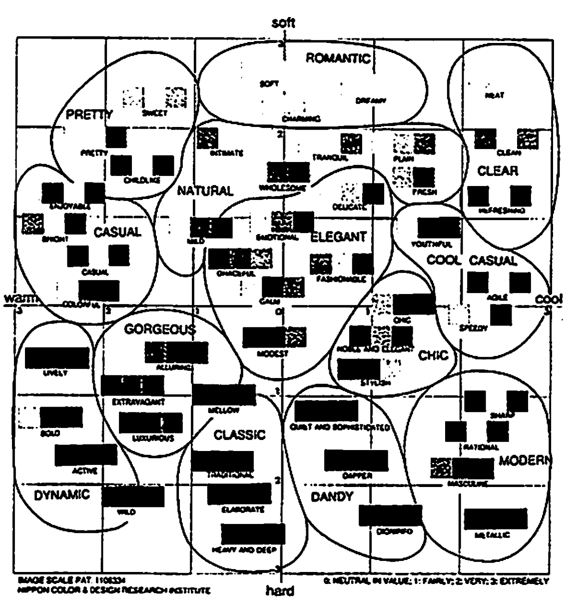


Fig. 2. Color image scale (Kobayashi, S.).

3.2 Physiological approach

The human sensory receptive function consists of an unconscious sensibility called the 'early kansei' as well as the mental activity caused by a high degree of recognition ability such as cognitive judgement [24]. There have been recent studies in various fields to determine the relationship between the subjective sensed by humans and the physiological index, taking changes in the physiological index as a kind of kansei information. The emotional changes obtained through measuring the facial skin temperature by using thermography [25] and the fatigue recorded in a three-dimensional optometer (TDO), which allows the simultaneous, real-time measurement of the three eye functions (ocular motion, focusing motion and pupillary control) [26] are indispensable to the evaluation of user-friendly machines.

3.3 Approach from information engineering

3.3.1 Image processing algorithm

The Hough transform, DP (dynamic programming), regularization, etc. are becoming popular as algorithms for simulating the human early visual sense.

The Hough transform is a method of extracting lines from noisy images, and is formally defined by equation (1),

$$\rho = x.\cos\theta + y.\sin\theta \qquad (1)$$

Since the transform function given by equation (1) can be extended, the resolution power used to detect lines can be tuned according to the typical human vision performance using "center-fine/periphery-coarse" characteristics. Since the performance of this camera system is similar to human visual action, it is called "askant glance camera vision (AGCV)" shown in Fig. 3 [27].

3.3.2 Neural network

This processing method is similar to the multivariate analysis described above, with a difference in that the network allows a non-linear mapping function and is equipped with a function which can determine the mapping function by learning from the sample data. The mapping function between kansei terms and physical quantity is generally presumed to be extremely complicated, and the model is, therefore, expected to represent the relationship between the two, which could not be done sufficiently by linear mapping using multivariate analysis. As concrete examples of this model, a research to verify the physiological knowledge by preparing to identity mapping functions on the neural network [28] and a system to recognize and synthesize the six basic facial expressions (happiness, surprise, fear, sadness, disgust and anger) are notable [29]. There is also an example of selecting whether to adopt or reject information during color discrimination in a neural network by carrying out a sensitivity analysis of the learned neural network [30].

3.3.3 Synthesis technology (CG, VR, simulation)

A new concept "Analysis-by-Synthesis," is about to be made concrete. Quite opposite to the modeling methods mentioned above, this is a method of making a machine that can provide kansei information by simulating the human kansei mechanism, and clarifying human kansei by using a machine that stimulates human kansei.

The kansei simulator is a tool which evaluates sensory factors such as a customer's tastes in product design. A virtual reality system, on the other hand, is helpful in determining the specifications of a product by providing a sensory experience regarding the look and feel of a product before it is produced. This is being effectively used in the interior design of a car [31], the visibility of a display [32], a check of the usability of a kitchen [33], etc.

The skill employing kansei factors in image synthesis to provide an image which is as real as possible is very important in such simulators. There are two main methods of representing a kansei image, one is a method of bringing the

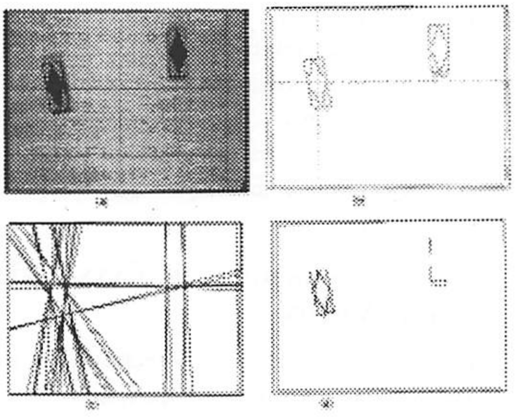


Fig. 3. Askant glance camera vision based on hough transform.

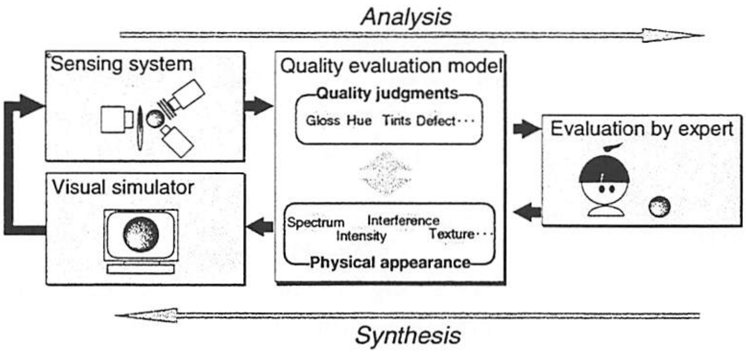


Fig. 4. The process of building up a pearl-quality evaluation system by analysis-by-synthesis approaches.

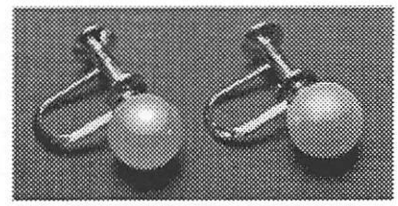


Fig. 5. Superimposition of synthesized images on photos of real pearls (original: color). Synthesized image (left) and real image (right)

image infinitely close to the physical phenomenon of the real object by using a mathematical model (physics-based modeling), and the other is a method of making the object seem more real than itself by effectively extracting (and sometimes even by exaggerating) the modeling features and movements, as in the case of deformation in a picture or portrait. In other words, these two methods can be summarized as follows:

1) Representation of reality
2) Representation of abstraction.

In the case of 1), the method of representing the specific features of a natural object such as quality, movement, etc. is now being studied in computer graphics. In recent years, technological simulations have been increasingly used in inspections to verify the visibility of flaws [7] and to search for optimum inspection conditions [34].

In the case of 2), a method of extracting and expressing intuitive features is under study in the portrait system. Further, some attempts are also being made using an image database system to retrieve images which are appropriate to a subjective impressive description such as "cool," "urban" and "refreshing," or inversely to generate new images by combining existing images of which the subjective impressions are represented by adjectives.

4. Actual Example of Kansei Machine Vision

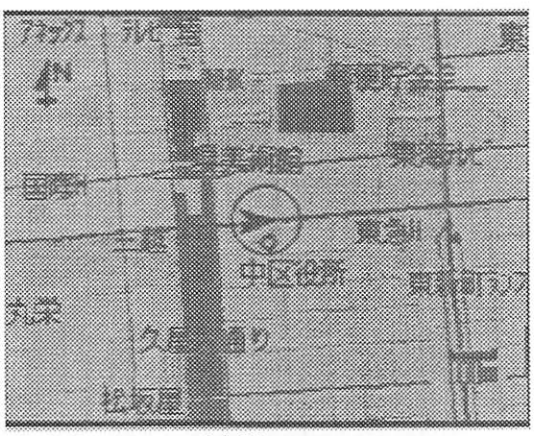
This section introduces some technologies that have already been put into practical use in industry, or are in the stage of research and development.

4.1 Pearl-Quality Evaluation System

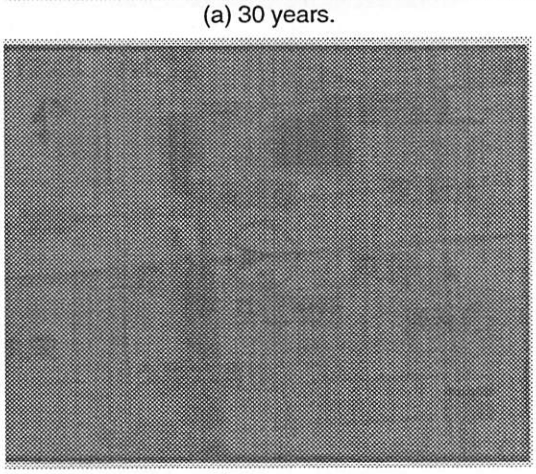
The unique color and glamorous luster of a jewelry such as a pearl together with the taste of an individual gives it a high value. The technical terms used to appraise pearls are extremely sensuous, and don't become common. Attempts are under way to systematize the kansei expertise of pearl [14]. The terms used to describe pearls such as "teri" (gloss) and "iromi" (hue) have been clarified, using a psychological approach, to be composed of a sense of depth and of grain. Further, sensitivity analysis of neural network is used to pick out the wavelength bands related to the color appraisal, improving the discrimination correspondence ratio of experts [30]. Moreover, in an attempt to make a simulator for pearl quality evaluation an "analysis-by-synthesis" approach (as shown in Fig. 4) was used, involving a physical model with multi-layer thin film interference specific to pearls and independent of the direction of the light source, has been suggested, enabling a real CG representation as shown in Fig. 5 [35]. The CG image is also evaluated through a psychological scale with terms like "pearl-like quality." Thus, an approach using both analysis and synthesis has become an important kansei machine vision methodology.

4.2 Reproduction and Compensation of Visual Characteristics

As a part of the improvement to be made in car-mounted display units such as navigation systems [19], the deterioration of visual function due to aging has been reproduced through computerized image processing, and a display method which is easier for aged people to see has been developed by compensating the display image according to the visual characteristics of them. The change due to aging is measured for three factors, the space frequency characteristics, the spectral characteristics and the focusing characteristic before being approximated respectively to convolution, color matching function and eyeball optical models. Fig. 6 shows images obtained by reproducting the visual characteristics affected by aging. Fig. 6b is dark and yellowish, with blurred details. The compensated image has its edge sections, including the high-frequency component being emphasized, with the blue color component being increased. In a functional evaluation, an excellent correlation is found to exist between the most visible compensated image and the age of the person concerned, proving the validity of the compensation method. This is of particular importance because the system is a design tool which is providing designers with the opportunity to experience intuitively the physiological kansei of the user.



(a) 30 years.



(b) 60 years.

Fig. 6. Comparison of the simulated images with a contrast sensitivity and a spectral transmittance (navigation display). (Higuchi et al.)

4.3 Facial Caricature via PICASSO System

Research on the face and emotion expression machine vision goes back to the 1970s, and is currently very popular with a number of diversified systems being targets of development. Among these the research into portrait making is attracting attention because of its comprehensive study of the general problems in the science of the face.

Figure 7 shows typical examples of the facial caricature generated by a machine vision system called PICASSO [21]. Figure 7a is a caricature of a former US President, and 7b is one of the great painter.

The PICASSO system can extract the individual features of a face by comparing the given face with a "mean face" introduced in advance ("mean face assumption" to extract the facial characteristics). If we can see some visual feasibility in the above caricatures, it can be concluded that the kansei information regarding the individuality of the face was successfully formulated by the basic method of introducing the mean face and comparing to it.

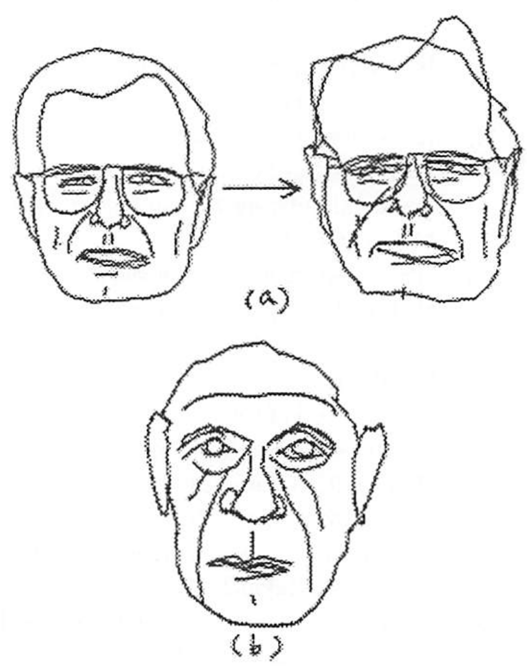


Fig. 7. Facial caricature using PICASSO system.

5. Conclusion

We have surveyed the trends of the technology for Kansei machine vision, and presented several examples. How to analyse the kansei information contained in various applications in order to clarify the mechanism has been stressed, and its feasibility and usefulness in various fields has been acknowledged. The kansei approach is warmly expected to be a breakthrough in machine vision technology. On the other hand, new industrial methods or algorithms are also eagerly awaited. In order to make machine vision technology effective in the future, it is urgent that methods common to Kansei engineering, such as a structural analysis of kansei itself and a technical method for kansei simulation are developed, and algorithms such as the extraction of kansei information from early vision, problems specific to human vision, are formulated. It is anticipated that cooperation between researchers in various fields will make this mission successful.

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