EXTRACTING FEATURE POINTS ON HUMAN EYE PHOTOGRAPHS

Shizuo SAKAMOTO Yoko MIYAO †
Johji TAJIMA
C&C Information Technology Research Laboratories, NEC Corporation
† NEC Software Limited

4-1-1, Miyazaki
Miyamae-ku, Kawasaki-shi
Kanagawa-ken 216, Japan

Abstract

A method is reported that robustly extracts eye-structure details, i.e. the inner and outer eye-corners and the upper eyelid, on a partial image with a human eye. It is very difficult to obtain stable results when using conventional methods, due to the weakness in resisting noise signals and wrinkles around the eyes. Therefore, local effective attributes on the image, regarding the eye-corners and the upper eyelid, which reflect a large amount of personality, are researched in order to obtain results robust against noise signals. A new computerized structure-extraction method, which is mainly composed of simple logical operations, is proposed. It was applied to a hundred human right eye photographs. Good results were obtained.

1 Introduction

An automatic procedure, for extracting details on human-face structures is required for the man-machine interface, human-identification, etc. The human-identification system in use of face images is an extremely interesting theme and can be applied at more various locations than in identifying finger-prints.

Due to the difficulty in obtaining fine face structures, some human-identification methods were recently reported, which were variations on the gray image matching algorithm [1][2][3]. However, they are not adaptable to various situations in which images are obtained. So, the human-identification method in use of face structures is more attractive.

For communication or identification between human beings, it is said that the eyes reflect a large amount of personality. Therefore, it is very important to obtain data on the fine structure of the human eyes. Several methods for extracting data on the eye-structure, i.e., the eye-corners, the shapes of upper and lower eyelids, the iris outline, have been tried, based on conventional methods [4][5]. However, unstable results, especially insecure results regarding eye-corners, were obtained. The reason was that only the edge information, for example, the zero-crossing of the Laplacian-Gaussian edge operator, is not sufficient for efficient identification. The edge information was so subject to interference from noise signals and wrinkles around a human's eye that other information had to be effectively used for obtaining data on the stable eye-structure, or it was necessary that other stable eye-structures were found. Therefore, the model, on which structure-extracting methods were based, and the attributes of the eye-structure on an image, were reinvestigated.

The area information is often used as much as the edge information. However, both the edge information and the area information, that are extracted independently from each other, cannot be simultaneously used. A new image-analysis technique was developed, that clearly detects various categories of edges, at first. Next, areas between two different-category edges are detected. After that, area information, i.e., the average brightness, variance and so on, is calculated within the detected areas.

A new structure-extraction method is proposed, based on the image-analysis technique, the extraction model concept, and the attributes on an image. This method has a few parameters with clear meanings. It is simply designed to mainly use logical operations. Experiments were carried out, using a computer, on the eyes in a hundred human photographs.

Edge Categories	First Differential Image	Second Differential Image
Step(+) edge	$+$	$+ \to 0 \to -$
Step(−) edge	$-$	$- \to 0 \to +$
Roof edge	$+ \to 0 \to -$	$-$
V-ditch edge	$- \to 0 \to +$	$+$

Table 1: Edge categories

The results obtained by the new method were compared with the eye-structure data selected by humans, and were found to be more able to withstand noise in the pickup-signals than data obtained by the conventional method. Moreover, this method is little influenced by folded eyelids, which often cause eyelid detection errors.

2 Technique for using edge information and area information

In image analysis, it is very difficult for both the edge information and the area information to be simultaneously used, because the edges do not generally match borders around the areas. Therefore, the following steps are proposed.

1. To further clarify the operation meaning, the four edge categories are detected in use of first- and second-order partial differential Gaussian edge operators, with the same coefficient matrix.

2. The four categories for areas between two different category edges, to certainly construct closed line, are detected.

Let four edge categories with clear meanings be given as a continuous line on Fig.1. The 'step(+)' and 'step(−)' edge categories in a direction are defined as an inflection point. The 'roof' edge category is defined as a maximal value point, and the 'v-ditch' edge category is defined as a minimal value point. These edges can be detected by examining signs of a convolved image with second-order partial differential Gaussian edge operator. The four categories and their relations with first- and second-order partial differential Gaussian edge operators are summarized in Table 1.

Individual areas, defined in Table 2, have areas between two different category edges. Area information, i.e., the average brightness, variance, textures, the shape of the area and so on, is calculated in the obtained areas. The area and the edge information can be used simultaneously in recognition procedures.

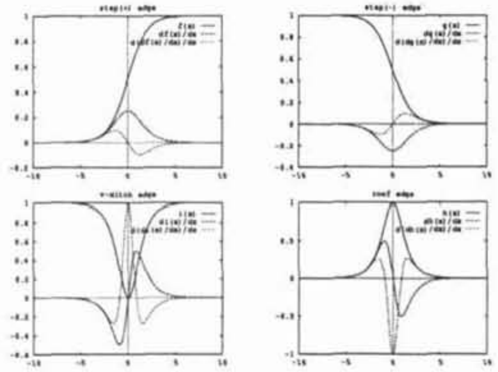

Figure 1: 'Step(+)', 'step(−)', 'v-ditch', and 'roof' edge

Area Categories	First Differential Image	Second Differential Image
Step(+) to Roof	+	−
Step(−) edge to V-ditch	−	+
Roof to Step(−)	−	−
V-ditch to Step(+)	+	+

Table 2: Area categories

Figure 2: An original image : Φ

3 Eye-structure features on an image

To obtain a stable eye-structure data extraction method, local effective features for the upper eyelids, and the inner and outer eye-corners on an image were researched, using the following criteria.

- Light conditions or wrinkles around an eye are stable, when points with a large curvature and deep interior are detected.
- The local minimal points can be detected in use of the first differential image, which is stronger than the second one in the convential methods.
- There are few local minimal points in the image.

Stable eye-structure is defined by the following features on the image.

1. The inner and outer eye-corners are defined as 'v-ditch edge' in every direction on the image, between the eyeball and other parts.
2. The upper eyelid consists of two parts. The first part is composed of 'step(−) edge' points between the skin and eyelashes. The other part is composed of 'v-ditch edge' points near the inner and outer eyecorners on the image.

In the following section, a new eye-structure data extraction procedure is proposed.

4 New eye-structure data extraction method

A new eye-structure data extraction method is proposed, as follows. The authors assume that a face image is already segmented and that the partial image with an eye becomes as given (Fig.2).

1. Preprocessing:
   (a) A partial eye image (Fig.2) is processed here. Convolved images are generated with first-order differential Gaussian along the 90-45-0–45 directions versus the x axis, and Laplacian-Gaussian edge operators. These edge operators have the same kernel function, the Gaussian function with standard deviations = 1 in every direction.

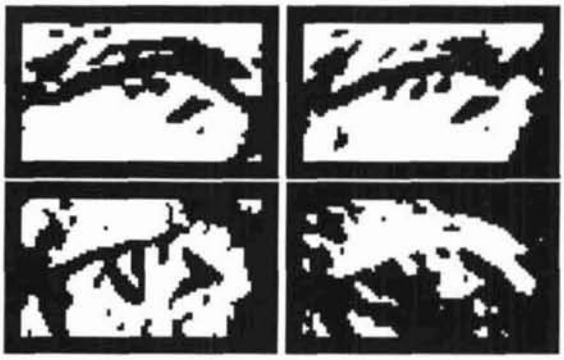

Figure 3: First differential images: $\Psi^{(1)}_{90} \cdot \Psi^{(1)}_{45} \cdot \Psi^{(1)}_{0} \cdot \Psi^{(1)}_{-45}$

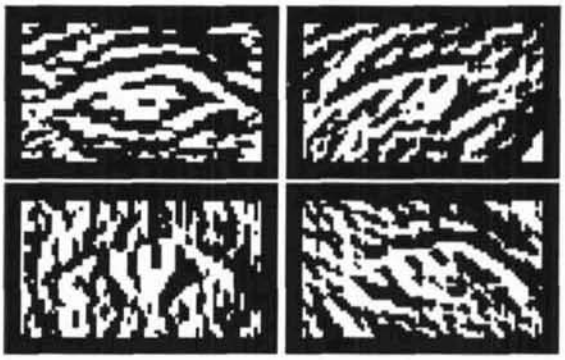

Figure 4: Second differential images: $\Psi^{(2)}_{90} \cdot \Psi^{(2)}_{45} \cdot \Psi^{(2)}_{0} \cdot \Psi^{(2)}_{-45}$

   (b) The convolved images are accomplished by setting up a threshold to generate to two regions; one positive and the other negative. In this paper, individual images are called $\Psi^{(i)}_{90} \cdot \Psi^{(i)}_{45} \cdot \Psi^{(i)}_{0} \cdot \Psi^{(i)}_{-45}$ $(i = 1, 2)$.

2. Upper-eyelid region detection:

   (a) The Ψ_a region (Fig.6) is obtained with the logical operation, $\Psi_a = \left(\neg\Psi_{90}^{(1)} \bigcap \Psi_\Delta\right)$, where $\neg$ shows logical negation and $\bigcap$ shows an intersection. The Ψ_a area is interpreted as the region between the step($-$) edge and the v-ditch edge. The upper-eyelid is detected along with eyelashes.

Figure 5: Laplacian Gaussian:Ψ_Δ

Figure 6: Upper-eyelid candidate

   (b) The Ψ_b region has connected regions for the Ψ_a, whose lengths are greater than a thresold value. The threshold must be wider than an iris width and narrower than an upper-eyelid width. This operation is used for erasing the iris region.

   (c) The Ψ_{uplid} (Fig.7) contains the Ψ_b region with the lowest brightness. This region is the upper-eyelid region.

3. Detecting the eye-corners and the upper eyelid near the eye-corners:

   (a) The $\Psi_{allvditch}$ is obtained with the logical operation, as Eq.1 and 2, where Ω is an operator that extracts region outlines, Υ is an operator that expands 1 pixel around regions. This $\Psi_{allvditch}$ has v-ditch edges in every direction. The expansion operation means that position uncertainty is tolerated for a size smaller than the standard deviation in the Gaussian function.

$$\Psi_{allvditch} = \Psi_{vditch,90} \bigcap \Upsilon\Psi_{vditch,45} \bigcap \Upsilon\Psi_{vditch,0}$$

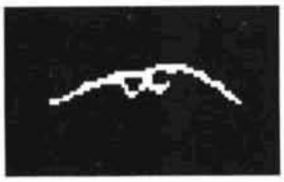

Figure 7: Detected upper-eyelid region.

$$\bigcap \Upsilon\Psi_{vditch,-45} \qquad (1)$$

$$\Psi_{vditch,i} = \Psi_i^{(2)} \bigcap \Omega\Psi_i^{(1)} \qquad (2)$$

   (b) The Ψ_{eyefp} value is obtained with the logical operation, $\Psi_{eyefp} = \Psi_{uplid} \bigcap \Psi_{allvditch}$. The Ψ_{eyefp} value has the eye-corners and the upper eyelid near the eye-corners.

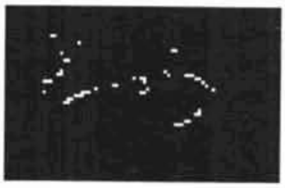

Figure 8: 'v-ditch edge' in four directions

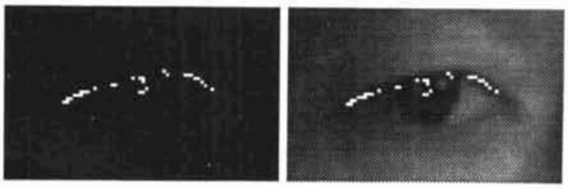

Figure 9: Results

5 Experimental results and discussion

This algorithm was applied to a hundred partial right eye images. Each original image has 512×512 pixel size with one big front face. Each partial image (Fig.2) with a big right eye has an 80×50 pixel size, determined by trimming at the hand-picked iris center point. One of the authors subjectively, but strictly, evaluated automatic extracted points for both the conventional method and the new method, in comparison with hand-picked points (Table 3).

The conventional methods are based on the second differential image. This new method is based on the first differential image. It is easy and stable to pick the eye-corners, which are almost at the points where the first differential image is equal to 0, by hand. It is especially difficult for the outer eye-corners to be detected by edge shapes which are calculated by the second differential image. Therefore, the eye-corners detected by conventional methods, may be distant from the hand-picked points, and 70~80 percent of the conventional-method results would be incorrect.

Figure 9 shows a correct detection example. The conventional methods carried out detections, based on the second different image, e.g. the convolving image with the Laplacian-Gaussian edge detector. Figure 5 clearly shows that the outer eye-corner cannot

Error reasons	Inner eye-corner	Outer eye-corner
Irregular face skin influence	2	6
Wrinkles around eyes influence	0	16
Broken line	3	0
Total	5	22

Table 3: Subjective result evaluation

Figure 10: One bad result:influence of wrinkles around an eye

Figure 11: One bad result:a broken line

Figure 12: One bad result:irregular face skin influence

be detected by only the 'step' edge shapes. The proposed method uses the 'v-ditch' edges, and good results are obtained.

Incorrect detection examples are shown in Figs.10 ~12. Figure 10 is influenced by the wrinkles around the eye. There were 16 out of 100 such cases. Humans may decide whether the image is ether eye-corners or not, by brightness undulations. This decision cannot be formalized.

Sometimes, the inner eye-corners cannot be detected, because of the large edge scale between the eye ball and the skin (Fig.11). Therefore, the edge-operator size optimization will be examined.

Detected points are far away from an eye (Fig.12), sometimes, because of the irregular face skin influence. This case can be simply avoided by introducing the upper-eyelid shape.

The new image-analysis technique was developed as one of the methods that integrate both edge and area information. The eye-structures exatraction method was proposed, based on this image-analysis technique, and applied to a hundred men's photographs. This method requires only a few parameters and has a simple design. Good results were obtained, especially for eye-corner detection. Because their positions were more accurately detected in comparison with results obtained using another technique based on the conventional method, this new technique is believed to be useful as a preprocessing for face identification.

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