DESCRIPTION OF EYE FIGURE WITH SMALL PARAMETERS

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ABSTRACT

The individuality of human face depends on the fine details of the facial components, and it is necessary to extract and to describe these detailed patterns in order to recognize human faces. In this paper, we propose a method to describe the eye figure with small parameters by classifying their patterns to typical groups.

First, an eye image is divided into parts such as eyelid and inner corner, and a set of 1-dimensional *slit projections* is obtained from the 2-dimensional intensity array. Then, the principal component analysis is applied to these projections to find the major axes which have typical features. The individuality of each eye is parameterized by the principal component scores. Effectiveness of the description is evaluated by generating sketch images based on the parameters extracted from real eye images.

1. INTRODUCTION

The technique to extract and to describe the individuality of human face can be practically used in many application fields such as man-machine interface and CG, etc. The individuality of a human face depends not only on the location of the facial components such as eye and nose, but also on the detailed patterns of each facial component. It is said that we get variety of information from the eyes while communicating with others. Especially, the shape of eyes has significant influence to the impression of the face.

In order to get the detailed structure of an eye, a method to detect the geometric shape such as the outline of eyelid has been proposed[1]. But it is hard to say that such geometric shapes can represent the individuality of an eye sufficiently. A method for extracting and describing the delicate nuance of the eye shape is necessary.

In this paper, we propose a method to describe the detailed pattern of an eye by combining the *slit projection* and the principal component analysis. The *slit projection* has been used for the extraction of rough structure of a face such as the position of facial components, but it is also effective for the extraction of detailed structures by changing the *slit* size, location, and orientation.

The principal component analysis has been used for extracting and classifying the whole image of an eye[2], but it is also effective for the delicate pattern of eyes by using the output of the *slit projection*.

2. EXTRACTION AND DESCRIPTION OF EYE FIGURE

The structure of human eye is shown in Figure 1. In this figure, the upper eyelid and the inner corner are the most important features in expressing the individuality of an eye. We extract these detailed patterns for the expression of the individuality.

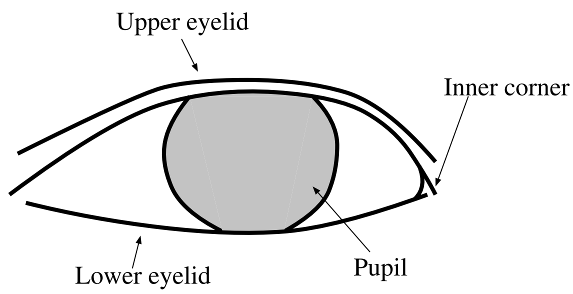


Figure 1: Structure of eye

2.1. Projection of local patterns

For an upper eyelid, since the horizontal wrinkles are important information in expressing the individuality, vertical Sobel operator is used to generate an edge image. This edge image is divided into five regions with equal width as shown in Figure 2, and a set of *slits* is applied to each region. A sequence of projections is

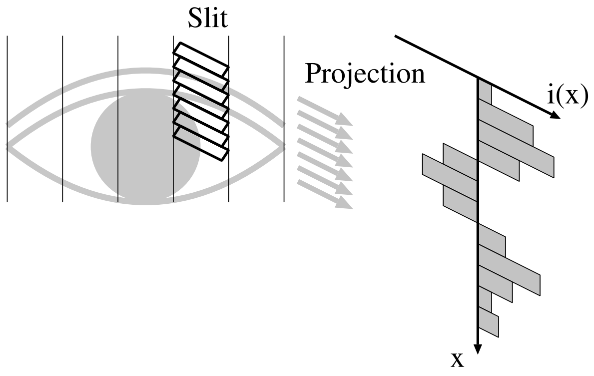


Figure 2: Projection of upper eyelid

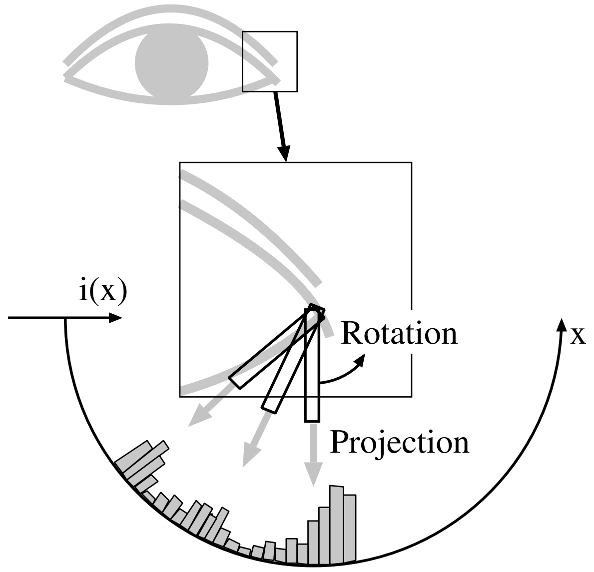


Figure 3: Projection of inner eye corner

obtained by changing the orientation of the *slits*, and then the projection with the largest variance is selected. The *orientation* which has the largest variance and the *peak location* in the projection are extracted as the geometric parameters.

The inner corner of an eye is the junction of the upper and lower eyelids. An edge image is generated by using the horizontal Sobel operator. By setting the intersection of the upper and lower eyelid as the origin, a set of *slits* is applied radially to the edge image, as shown in Figure 3.

By using these *slit projections*, 2-dimensional intensity patterns are represented as 1-dimensional projections.

2.2. Classification of projection patterns

The projection patterns taken from many eye images are classified into typical groups. A projection obtained by using n-*slits* is represented by an n-dimensional vector. The principal component analysis is applied to these vectors. Since the principal components are the axes that express the typical features, each projection is classified into a group based on the sign of principal component coefficient. The feature of each eye part is parameterized with the sign of its principal component coefficient. For the case of upper eyelid, geometric shape is parameterized with the *orientation* and the *peak location* in addition to the coefficient signs.

3. SKETCH GENERATION

It is necessary to evaluate whether the description preserves the individuality of each human eye figure. For this purpose, a sketch image is generated by using the parameters obtained. The effectiveness of the description is evaluated by comparing the impressions that a human observer gets from the original image and the sketch image.

To synthesize a sketch image, an average image and a few typical *local sketches* are prepared. A sketch image is synthesized by overwriting one of the *local sketches* onto the average image. The average image is obtained by the intensity average of the given set of eye images. The *local sketches* express the common features of each classified group. For the upper eyelid, a *local sketch* is prepared by synthesizing the intensity pattern based on the principal components. For the inner corner, a *local sketch* is prepared as the most typical pattern which is clipped from an image in each classified group.

Figure 4: The average image

4. EXPERIMENT

28 right eyes of front face without glasses were taken as input images. These images were normalized by size and location manually.

As the result of the principal component analysis for the upper eyelids, the first p.c. (principal component) indicates whether an eye has *double eyelid* or *single edged eyelid*. The second p.c. indicates whether the eyelid is *clear* or *narrow*. The signs of the coefficients of the first and second components indicate the group as shown in Table 1. For example, Figure 5(a),(b) and (c) are classified as *clear, narrow*, and *single-edged* respectively.

As the result of the principal component analysis for the inner corner, the first p.c. indicates whether the corner is *round* or not. For non-rounded corner, the second p.c. indicates whether the corner is *sharp* or *down pointing*. The signs of the coefficients of the first and second components indicate the group as shown in Table 2. For example, Figure 6(a) and (b) are classified as *sharp corner*, Figure 6(c) and (d) are classified as *down pointing corner*, and Figure 6(e) and (f) are classified as *round corner*.

The same analysis is performed manually for the comparison. Tables 3 and 4 show that the automatic classification by the principal component analysis is almost correct expect for a few cases.

The input images and their sketch images are shown in Figure 7. The input images are in the upper row (a)–(d), and the sketch images are in the lower row (e)–(h). (a) has a *clear double eyelid*, (b) has a *narrow double eyelid*, and (c) and (d) have a *single edged eyelid*. Also (a) and (d) have a *sharp corner*, (b) has a *down pointing corner*, and (c) has a *round corner*.

Since a sketch image preserves the important features of an eye, it is clear that our method is effective to represent the detailed figure of an eye.

Table 1: Classification of upper eyelid

	sign of the first p.c.	sign of the second p.c.
Clear double eyelid	+	−
Narrow double eyelid	+	+
Single edged eyelid	−	no relation

Table 2: Classification of inner corner

	sign of the first p.c.	sign of the second p.c.
Sharp corner	+	+
Down pointing corner	+	−
Round corner	−	no relation

Table 3: Comparison of the automatic and the manual classifications for upper eyelid

Classification by Principal component analysis \ Classification by Human	Clear double eyelid	Narrow double eyelid	Single edged eyelid
Clear double eyelid	4	1	0
Narrow double eyelid	1	6	0
Single edged eyelid	0	0	16

Table 4: Comparison of the automatic and the manual classifications for inner corner

Classification by Principal component analysis \ Classification by Human	Sharp inner corner	Down pointing inner corner	Round inner corner
Sharp inner corner	6	2	1
Down pointing inner corner	0	7	2
Round inner corner	1	0	9

5. CONCLUSION

We showed that the detailed patterns of an eye can be extracted and classified by using *slit projections* as far as their orientation and location are carefully controlled. We think that our method can also be used for compressing and synthesizing eye images.

6. REFERENCES

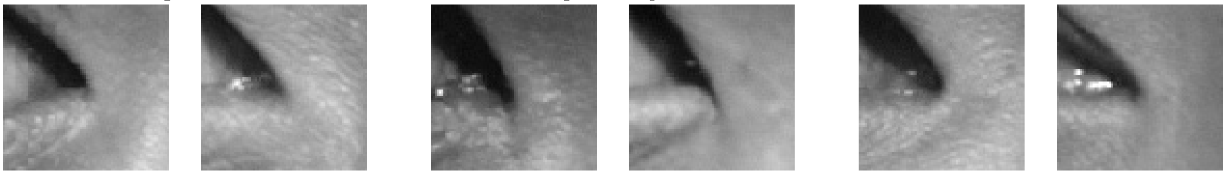
[1] Alan L. Yuille, David S. Cohen and Peter W. Hallinan, "Feature extraction from faces using deformable templates", Proc. IEEE Conf. on Computer Vision and Pattern Recognition, pp. 104–109 (1989)

[2] M.A. Shackleton and W.J. Welsh, "Classification of Facial Features for Recognition", Proc. IEEE Conf. on Computer Vision and Pattern Recognition, pp. 573–579 (1991)

(a) Clear double eyelid (b) Narrow double eyelid (c) Single edged eyelid

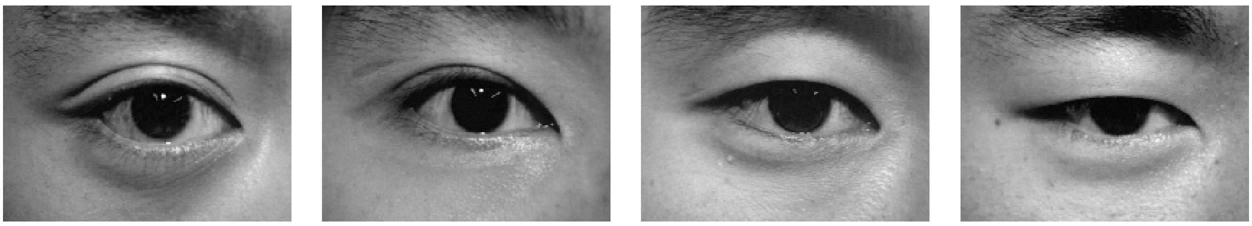
Figure 5: Classification of upper eyelid

Sharp corner Down pointing corner Round corner



(a) (b) (c) (d) (e) (f)

Figure 6: Classification of inner corner



(a) (b) (c) (d)

(e) (f) (g) (h)

Figure 7: Results of sketch generation (top: input images, bottom: their sketch images)