Shape from Shading-Based Eigenface

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ABSTRACT

Face recognition is more and more popular and used in many ways such as entrance guard, checking attendance, and even sorting pictures in on-line album. Eigenface method is a traditional and robust way to accomplish face recognition [1]. But many researches show that eigenface is easily influenced by the direction of light source. Even if there are some methods supposed to enhance eigenface method [2], it is still difficult to perfectly avoid the influence of light source condition. Therefore, the depth and gradient information are used to replace the illumination of picture to avoid the influence of light source condition.

1. INTRODUCTION

Eigenface method uses the illumination of pictures to construct the principal component faces. Because it is based on illumination of pictures, the pictures we want to recognize must be taken under almost the same lighting conditions. In order to decrease the influence of light source condition in eigenface method, we use the depth information to replace the illumination of picture. Therefore, we have to rebuild the information of the third dimension from a 2D image. Briefly, we use the skill of shape from shading [3] before the operation of eigenface to enhance the accuracy of face recognition.
By taking pictures from many angles of light source directions, we can make face recognition more accurate than original eigenface method.
Therefore, what we are concerned about is how to use the extra depth information to make face recognition more accurate. For example, we can reposition the face images with the position of the nose tip or some special (maximum or minimum) depth feature point.

2. SHAPE FROM SHADING-BASED EIGENFACE

2.1. CONCEPT

The existing method of face recognition is often influenced by the light source direction. Pictures below are the statue of Mozart illuminated by two different light sources. On the left side (Fig. 1), the statue is illuminated by light source coming from front. On the right side (Fig. 2), the light source comes from the right front direction. It will be confusing to the face recognition system and judged to be different face because of the difference of illumination system.

Fig. 1 Light source from front.

Fig. 2 Light source from right front.

However, the depth and gradient information of object in real world is invariant to different illumination systems. In order to decrease the erroneous recognitions which is caused by the illumination system, it is a thought that to use the 2D picture to re-model its 3D depth and gradient. Shape from shading is a way to recover the depth and gradient information from 2D pictures. With the depth and gradient information, we can construct a face recognition system less affected by light source.

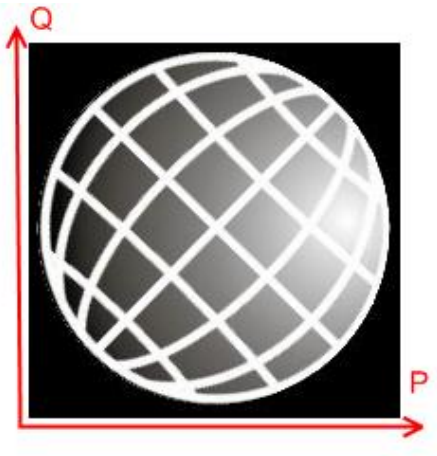

Fig. 3 The reflection map in Fig. 2.

The picture above is the light source direction of Fig. 2. After shape from shading, the gradient of the statue of Mozart can be reconstructed.

The picture below is the result of removing the original light source from right front and relights it by light source coming from front. The result is much similar to Fig. 1 than Fig. 2.

Fig. 4 Reconstruct Fig.2 illuminated by front light source.

2.2. ESTIMATING LIGHT SOURCE

However, how to estimate the light source direction of a 2D face picture? It is a really big problem in computer vision. Fortunately, human front face in real world is almost symmetric and the region of nose tip on human face approaches a perfect Lambertian sphere. Furthermore, the region of nose tip on human face would not be easily shadowed by other parts of organs on the face. Therefore, the direction of light source can be estimated by the following method.

First, find the region around the nose tip in face picture with some 2D picture matching methods or classifiers and equalize the image of the region. After that, we can compare the image to some existing images including perfect Lambertian sphere illuminated by different directions of light source and use it to estimate the direction of light source. Second, shape from shading with the direction of light source which we got on the first step and extract forehead or jaw from the result. Third, test the result coming from second step to judge if the gradient of x-axis is symmetric. If not, fine-tune the direction of light source and return to the second step. Repeat it continuously until we can not get more symmetric gradient result.

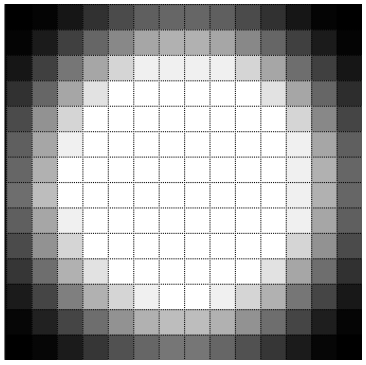

Fig. 5 A perfect Lambertian sphere illuminated by light from front.

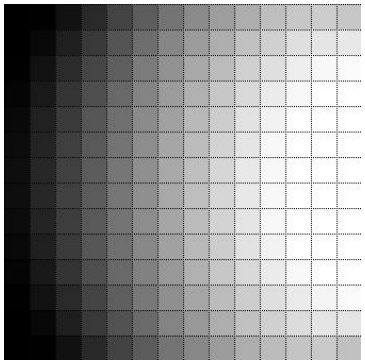

Fig. 6 A perfect Lambertian sphere illuminated by light from right front.

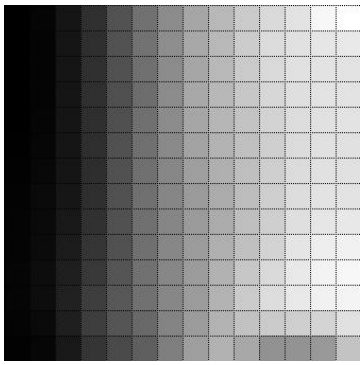

Fig. 7 The region around the nose tip of Fig. 2.

Fig. 7 represents the region around the nose tip of Fig. 2. As pictures above, it has minimum least mean square to Fig. 6. Therefore, the right front direction of light source can be used as estimation in this case.

After shape from shading, the gradient of x-axis shows in Fig. 8. We can notice that the gradient of x-axis in forehead and jaw are almost symmetric, it means the estimation of light source direction is perfect and we will not fine-tune the result.

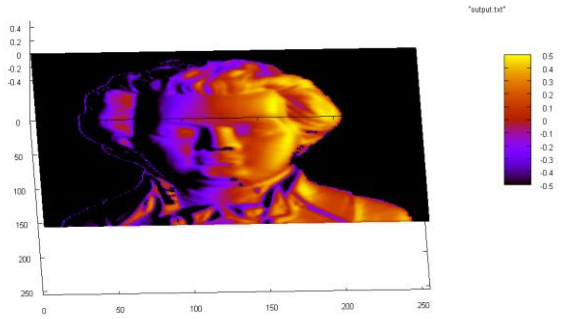

Fig. 8 The gradient of *x*-axis after shape from shading.

3. EXPERIMENT

The pictures in ORL face database [4] are used to verify this paper. The first face picture in every directory of ORL face database will be taken to be our face training images. Eigenfaces are then extracted out of the image data by means of Principal Component Analysis (PCA). After training, we will decompose pictures of the same face but illuminated by different light sources into face subspace. There are pictures with light coming from front, light coming from other directions besides front, and light coming from other directions besides front but reconstructed by shape from shading. Moreover, we will compare three situations referred above and find if the distance on face subspace is closer after being reconstructed by shape from shading.

4. RESULTS

First, the pictures of status of Mozart are used for test. Picture A is the face with light coming from front; Picture B is the face with light coming from right; and Picture C is the result of Picture B where its light source had been reconstructed by light coming from front. We get the result that distance in face subspace from A to B is farther than it from A to C. It means that after reconstruction by shape from shading, Picture C is more similar to A than B which can be easier to be recognized by face recognition system.

Table 1 The picture set of status of Mozart.

Picture name	Picture A	Picture B
Picture		
Light source direction	Light source coming from front	Light source not coming from front
Distance in face subspace	9469	
Picture name	Picture A	Picture C
Picture		
Light source direction	Light source coming from front	Reconstruction from Picture B
Distance in face subspace	4443	

In Table 2, real face is used to test the result of reconstruction. The distance is calculated shown below which tells us reconstruction is really useful for face recognition.

Table 2 The picture set of real face.

Picture		
Light source direction	Light source coming from front	Light source not coming from front
Distance in face subspace	5217	
Picture		
Light source direction	Light source coming from front	Reconstruction from Picture B
Distance in face subspace	4660	

5. CONCLUSION

As the result of experiment, we can say that shape from shading really makes Eigenface-based facial recognition system more robust to different light source conditions. However, shape from shading needs CPU supports which must take more time than just recognition. But it is worthwhile because the accuracy could be improved and the added time is acceptable in most of resent CPU power. Besides, the way used to estimate light source direction is some kind of trial and error method. It will consume CPU power. Therefore, how to perfectly judge the direction light source coming from is another difficulty to be discussed.

6. Reference

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