Automatic Pixel Boosting for Face Enhancement in Dim Light

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Abstract: Images in dim light cause many problems such as illumination variation which includes shadow effects. The enhancement of dim faces is difficult and challenging. Image enhancement can be useful for face detection and recognition. In this paper we contribute a new method called 'Automatic Pixel Boosting' to access and boost each pixel individually by using curve fitting. Eigencurves are used for improving the enhanced images. Skin probability ratio test is used for APB evaluation. Eigenfaces and Karhunen-Loeve algorithm and FaceSDK software are used for evaluating the performance of APB in comparison to Histogram Equalization by using a small database.

1. Introduction

The problem of dim light reduces the face detail because of shadow and illumination variation. This also reduces the ability of face detection/face recognition [1], [2]. Solving this problem, the image enhancement [3], is the very first important step. One tool in PhotoShop is available called 'curves' which the user can increase/decrease the curve of input intensity manually. However, the user has to be familiar with the data and approach. This tool can take time to find the best result because there are many possible curves and it is not always not easy to make an optimal decision. Therefore, we propose the new method called '*Automatic Pixel Boosting*' or *APB* to do this task automatically. The idea of APB is to boost and rearrange each pixel intensity independently. We use gray images from YalesDatabaseB [4]. We assume that the face under the best illumination has normal distribution. Before and after using APB the skin probability from the ground truth with 99% confidence level is used for testing the face skin of dim images. We also increase the effectiveness of APB by using PCA [5] to identify the set of eigencurves. Next, we choose the best curve which converts the dim image to give an optimal solution. APB is simple, but very effective and robust.

2. Evaluation Methods

The 'skin test' is used to evaluate APB. It can be observed that the face image with normal lighting can be well approximated with a normal distribution. Firstly, we set up the skin test by measuring the mean μ and the standard deviation σ of this face skin sample from the ground truth so that we can use them to convert the dim image intensity x to the skin probability densities by using the normal pdf:

$$f(x \mid \mu, \sigma^2) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{\sigma^2}} \quad \ldots\ldots(1)$$

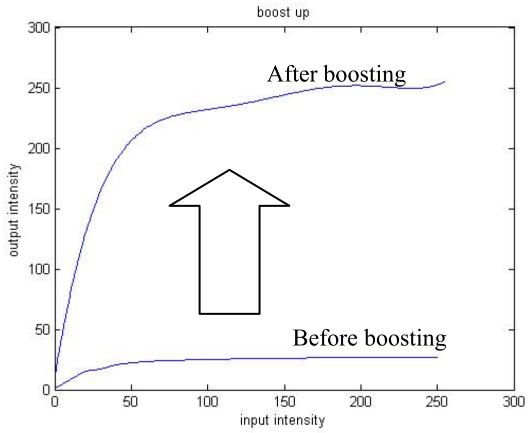


Fig.1. Boost up.

The idea of this skin test is to measure how close the face skin is to the ground truth. By using 99% confidence level of the ground truth image, the skin intensity interval is $\mu \pm 3\sigma$. The number of face pixels which is in this interval is counted.

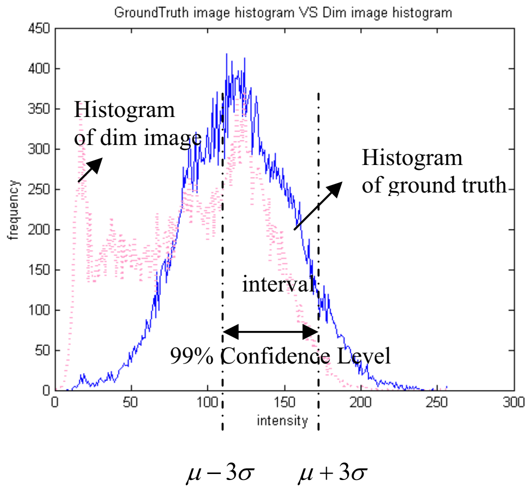


Fig.2. The skin intensity interval.

Given that n_D, n_G are the numbers of the dim faces and the ground truth face pixels in this confidence interval respectively. Given that t_D, t_G are the total number of pixels from the dim face and the ground truth face respectively. The skin probability of the ground truth face S_G within this interval is:

$$S_G = \frac{n_G}{t_G} \quad \ldots\ldots\ldots(2)$$

The skin probability of the dim face S_D within this interval is:

$$S_D = \frac{n_D}{t_D} \qquad \text{……….(3)}$$

The enhanced face from each dim face is compared to the ground truth face. The probability ratio between S_G and S_D is given:

$$R = \frac{S_D}{S_G} \qquad \text{……….(4)}$$

This ratio is measured before and after using APB. If the ratio is approximately 1, then the enhanced image is close to the ground truth.

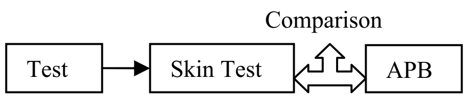


Fig. 3. The process of evaluation

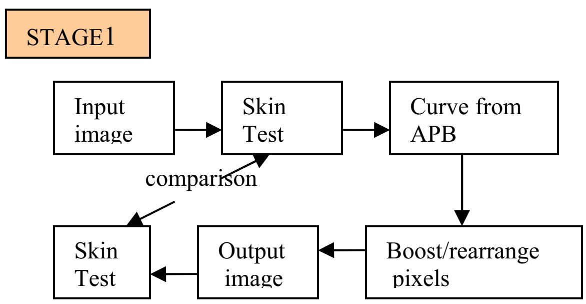
After obtaining 54 curves from 54 images, we use PCA to generate 54 eigencurves. To optimize the best enhanced image, we choose the best eigencurve converting the same dim image. This best enhanced image gives a probability ratio nearly to 1.

3. Experimental Data

We randomly selected 54 images with various pose and lighting variations from YalesDatabaseB and we randomly choose 54 images from them. The total number of dim image is 216 images. The ground truth is used for skin test. Each frontal image is in the same position, but different light/pose direction. The shadow makes the task more difficult. The ambient image (totally dark) is omitted as this gives a poor result.

4. A Brief Algorithm

There are 2 stages for APB. Stage1 we use APB without PCA. Stage2 is to increase the ability of APB by using PCA. After using APB, we obtain 54 curves and generate 54 new eigencurves. Next, we optimize those curves and show the results. Note that after obtaining 54 eigencurves, we do not need to use the ground truth because any dim images or different person images can be enhanced automatically.



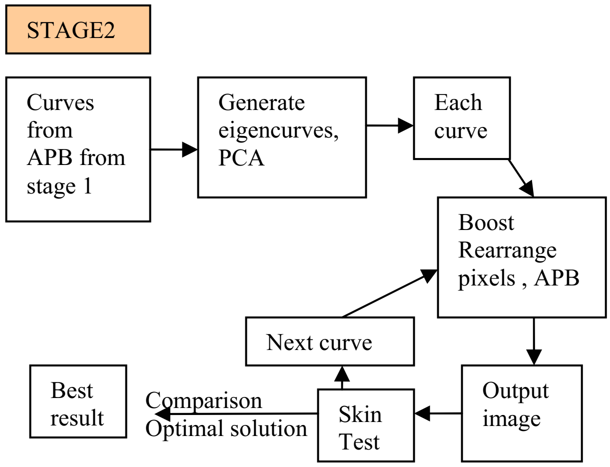


Fig.4. Stage1 is the process for each dim image and Stage2 is to increase the effectiveness by generating new eigencurves.

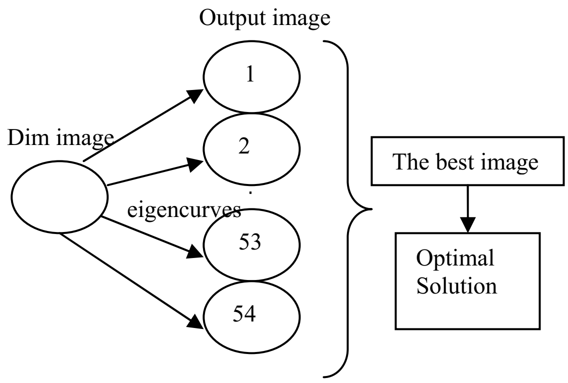


Fig.5. Finding Optimal Solution.

5. Evaluation Result

One dim image is randomly chosen and measured by the skin test. The probability ratio is 0.0125. Next, APB is used for drawing one curve. The dim image is enhanced to the new image where the ratio increases to 0.5567. The dim image is enhanced immediately and effectively. In Stage2, the best curve out of 54 eigencurves is used to convert the same dim image again. The enhanced image (with PCA) is better than the enhanced image from Stage1 (without PCA). The ratio is finally reached to 1.0157. The PCA eigencurves generalize well to previously unseen images. The dim images in Fig.8 are novel images, enhanced using eigencurves generated from the earlier training process. The resulting eigencurve enhanced images have good contrast and help to demonstrate the usefulness of this procedure for the general case.

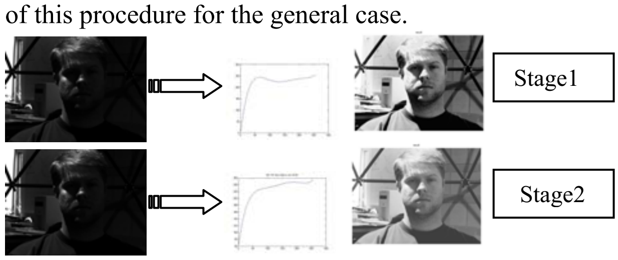


Fig.6. Results from Stage1 and Stage2.

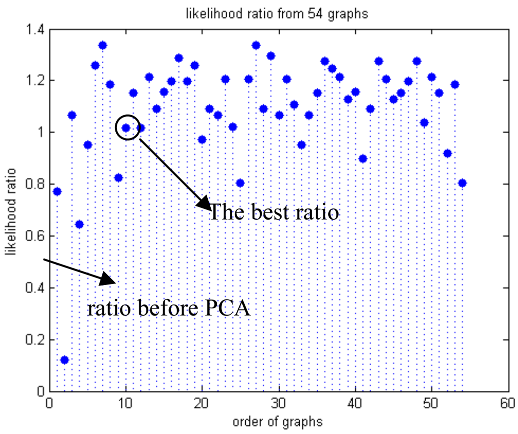


Fig.7. Probability ratio after using 54 eigencurves.

ratio=1.01 ratio=0.77 ratio=0.95

Fig.8. Dim images are in the first row. Enhanced images are in the second row.

6. Comparison with Histogram Equalization

Two recognition systems, i.e. EigenFaces and Karhunen-Loeve[6] and FaceSDK[7] are chosen for comparison APB and Histogram Equalization.

6.1 EigenFaces Method and Karhunen-Loeve

The two small databases are set up. The ground truth images of 10 people are used for training. There are 16 dim images of the first person used for testing. These test images are selected because of very poor light and which we then use to test APB and Histogram Equalization.

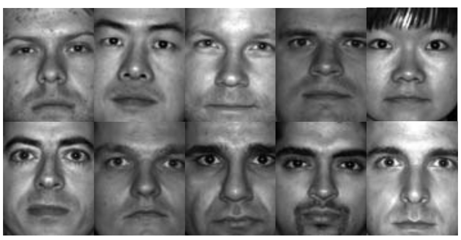
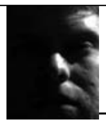
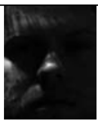
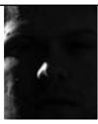


Fig.9. A ground truth image of each person.

The experimental results are shown in Table1. The left most images are the original dim images and the software cannot match them to the right class. The enhanced images from APB are in the middle. The right most images are from Histogram Equalization. From this test, two APB images are better results than for the Histogram Equalization, and another four are correct for both methods. Six images from Histogram Equalization give better results than APB. However, this database is very small and still need more tests.

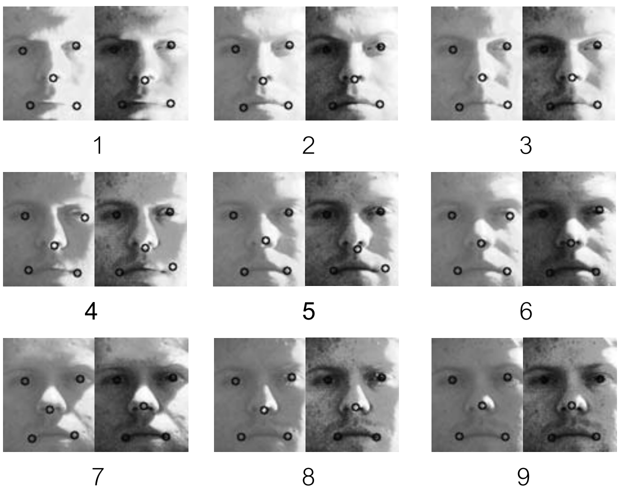
Table 1 Results from EigenFaces and Karhunen-Loeve

No.	*Test Im*	*APB Im*	*HistEq Im*
1 recognition	 incorrect	 **correct**	 incorrect
2 recognition	 incorrect	 incorrect	 incorrect
3 recognition	 incorrect	 incorrect	 incorrect
4 recognition	 incorrect	 incorrect	 **correct**
5 recognition	 incorrect	 incorrect	 incorrect
6 recognition	 incorrect	 incorrect	 **correct**
7 recognition	 incorrect	 **correct**	 **correct**
8 recognition	 incorrect	 incorrect	 **correct**
9 recognition	 incorrect	 incorrect	 **correct**
10 recognition	 incorrect	 incorrect	 **correct**
11 recognition	 incorrect	 incorrect	 incorrect

No.	*Test Im*	*APB Im*	*HistEq Im*
12 recognition	 incorrect	 **correct**	 **correct**
13 recognition	 incorrect	 **correct**	 **correct**
14 recognition	 incorrect	 **correct**	 **correct**
15 recognition	 incorrect	 **corrrect**	 incorrect
16 recognition	 incorrect	 incorrect	 **correct**

6.2 FaceSDK

We also use another commercial software called 'Luxand-FaceSDK' to test the enhanced images from APB and Histogram Equalization. The test database has the same dim images of previous Eigenfaces test. Note that the software did not find the face features for 14 out of 16 of the dim images because of the poor lighting. After using this software, we manually mark those eyes, tip noses, mouths as shown in Figure 10. There are a couple of three results in each row. The left image is enhanced from APB and the right image is enhanced from Histogram Equalization. From the results no.4, the right eye from APB has an error, and the tip nose and the right corner of the mouth from Histogram Equalization have some error. The results no.5 in the right image has some error at the tip nose and the right corner of the mouth.



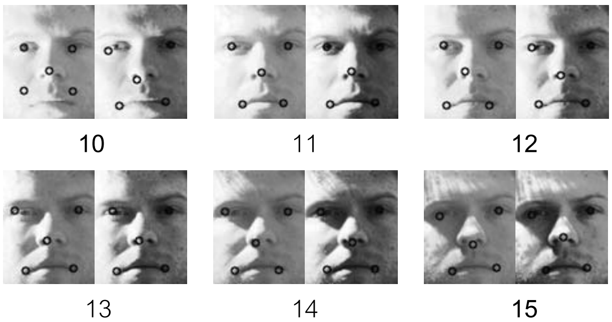


Fig.10. Marked Features from the software FaceSDK.

Both enhanced images from the results no.10 have some error. From the results no.12, the left eye from APB can be marked better. The tip of the nose from APB, for result no.15, is marked a little lower than the tip of the nose from Histogram Equalization. Other enhanced images from above can be marked correctly.

7. Conclusions

APB is able to enhance dimly light images, which is useful prior to recognition and in particular prior to facial features detection. More tests are needed to compare APB with other methods such as Histogram Equalization.

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