An Improved Difference of Gaussian Filter in Face Recognition

Shoujia Wang
College of Computer Science and Technology, Jilin University, Changchun, China 130012
E-mail: wangsj035@163.com

Wenhui Li¹, Ying Wang, Yuanyuan Jiang, Shan Jiang, RuiLin Zhao
College of Computer Science and Technology, Jilin University, Changchun, China 130012
¹ Corresponding author’s e-mail: liwh@jlu.edu.cn

Abstract—In this paper, we analyze an improved DOG filter with different parameters in horizontal and vertical directions and the improved filter uses oval recognition domain instead of round recognition domain of classic DOG filter. The improved filter is used to compare with major illumination pretreatment methods. The experiment result shows the improved method has better recognition and false detection rate.

Index Terms—face recognition, Illumination pretreatment, Difference of Gaussian filter, PCA, LDA

I. INTRODUCTION
Since Bledsoe¹ submits his technical report of facial recognition in 1966, algorithms of face recognition become a popularity research field of computer science ²³. In nearly 50 years, many researchers study in this field and find lots of achievements⁴⁵. When FERET (Face Recognition Technology) shows its report of face recognition algorithms in year 1996, scientists find that the main researches are not robust enough with illumination and pose. Now illumination pretreatment is an important research domain of face recognition.

Nowadays, we always use the following methods to process illumination pretreatment. They are histogram equalization (HE for short)⁶, Gamma correction (GC for short)⁷, local contrast enhancement (LCE for short)⁸, discrete cosine transform (DCT for short)⁹ and difference of Gaussian filter (DOG for short)¹⁰, etc. All these methods are used to improve face recognition rate, but there have some disadvantages.

The main idea of HE is to mapping gray scales of an original image’s pixels to another image with probability density uniform distribution of grayscales. This method could weaken impact of illumination from mapping. But it decreases gray scales and leads to lose some details.

The Algorithm GC controls luminosity of original images with parameter Gamma. Thus, it decreases impact of illumination. But the correction value cannot solve practical problems when illumination changes with highlight, transition and shade. Moreover, it is always a bit distortion when an image changes with gamma correction. Especially, the distortion is obvious with colorful images.

LCE algorithm makes statistics of mean luminance of every area. Then it makes logarithm transformation by luminance of the calculated pixel and mean luminance of the pixel’s area. Though LCE could strengthen local image details, the disadvantage is that it cannot improve dynamic range of whole image.

DCT is an orthogonal transformation. When we use DCT parameters to rebuild original image, we save some low frequency components of discrete cosine transform and drop lots of high frequency components. It uses inverse transformation to get a resume image which is similar to original image. The resume image is inconspicuous distortion because it contains most important information. But it depends on original image seriously and it needs long time for recognition.

DOG filter is a kind of filter that makes convolution operations with original grey image to smooth original image in space domain. Its transfer functions are two Gaussian differences with different widths.

In this paper, by compared with these algorithms of face recognition, we give an improved DOG filter to process illumination pretreatment at first. Secondly, we combine the improved DOG filter with PCA-LDA methods. We use PCA to reduce dimensions and LDA to recognize faces. Then we compare all these five methods which are combined with PCA-LDA. All recognition images are from the Yale B face database and AR face database. Finally, we study results of all experiment and find that the improved DOG filter shows best behavior. The improved method increases recognition rate by same poor illumination.

II. IMPROVED DOG FILTER
A DOG filter image is constructed by convolutions of an original image and DOG filter. In this paper, 2-dimensional DOG filter is used usually. We know the formula of 2-dimensional Gaussian function is formula (1).
Moreover, we use convolution kernel to filter signal by convolution integral, we get \( h(x, y) = e^{-\frac{x^2+y^2}{2\delta^2}} \) (1).

Define these 4 parameters by formula (3).

\[
W_0 = \min \{|u| : \frac{dE(u)}{du} = 0, u \neq 0\}
\]

As we known, \( E(u) \) is envelope of frequency spectrum and \( W_0 \) is width of frequency band. When \( \lambda \) is the gain of filter, we divide parameters \( \lambda \) and \( u \) to two conditions. One is \( 0 < \lambda < 1 \) and the other is \( \lambda > W_0 \). As we known, when \( \lambda \rightarrow +\infty \), the transfer function can simplify to \( D_0(x, y) = 1 - e^{-\frac{x^2+y^2}{2\delta^2}} \). Then we can make inverse Fourier transform to get impulse response of \( D_0(x, y) \).

DOG. Its formula is \( g(x, y) = \sigma(x, y) - e^{-\frac{x^2+y^2}{2\sigma^2}} \sqrt{2\pi\sigma^2} \) with \( \sigma = 1/2\pi\delta \) and \( \sigma(x, y) \) is a unit impulse function. Moreover, we use convolution kernel to filter signal by convolution integral, we get \( h(x, y) = \int_{-\infty}^{\infty} H(x, y) g(x-o, y-o) do \). When signal’s frequency is larger than \( W_0 \), the signal is in pass band of filter and gain = 1. In other words, it means that component of high frequency passed with distortion free[12]. Of course, when signal’s frequency is smaller than \( W_0 \), the gain is smaller than 1 and decreases by inverse proportion to smoothness. To consider with intensity dependent spread (IDS for short)[14], we find variance \( \sigma(x, y) = 1/I(x, y) \). Then we can calculate \( \lambda \).

When we find the proportion relation of \( \delta_{x1} \) and \( \delta_{y1} \), we define proportion R as formula (5).

\[
R = k/(k + avg(D(i, j)^2))
\]

So we find \( \delta_{y1} = R \delta_{x1} \). Moreover, \( \delta_{x2} \) and \( \delta_{y2} \) are calculated by similar steps. So we can use formula (4) to design an improved DOG filter.

### III. FACE RECOGNITION ALGORITHM AND PROCESS

In this paper, we use principal component analysis algorithm (PCA for short) and linear discriminant analysis (LDA for short) algorithm to recognize faces.

When we make standardization of training object by \( X_{avg} = (X-X_{avg})/D_{avg} \), we get principal component by \( UT (XX^T)^{-1} U = \Lambda \). Hereinto, \( X \) is training sample set with size \( N \times P \), \( N \) is sample and \( P \) is size of it. \( X_{avg} \) is mean image of \( X \) and \( \Lambda \) is a diagonal matrix make up of eigenvalues and \( U \) make up of eigenvectors. To select eigenvalue \( U_m \) from the first \( m \) eigenvalues, we get \( X \)'s mapping is \( P = U_m X \). For each image \( X \), we can make recognize by compare its mapping to training sets. It is PCA algorithm.

LDA is another algorithm of face recognition. We design a set of linear transform and get the most discriminatingly characters of low-dimensional from high-dimensional space. So the best mapping function is \( W = \arg \max_{W} \left| W^T \Sigma_1 W \right| \). Then we find that improved Gaussian function in formula (4) which is constructed by formula (2).

\[
D_{\delta x_1, \delta x_2, \delta y_1, \delta y_2}(x, y) = \frac{1}{2\pi \delta_{x1} \delta_{y1}} e^{-\frac{1}{2} \left( \frac{x^2}{\delta_{x1}^2} + \frac{y^2}{\delta_{y1}^2} \right)} - \frac{1}{2\pi \delta_{x2} \delta_{y2}} e^{-\frac{1}{2} \left( \frac{x^2}{\delta_{x2}^2} + \frac{y^2}{\delta_{y2}^2} \right)}
\]

So we have to find \( \delta_{x1} \) and \( \delta_{y1} \). At first, we give an adjustable method to find \( \delta_{x1} \). We consider about limit condition of a point \((x, y)\).

1. We assume nearly of point to filter is smooth, in other words, grey values of every point are same. Then we get that \( D(x, y) = 0 \). \( D(x, y) = I(x, y) - M(x, y) \) is difference between grey of \((x, y)\) and grey mean value at \((x, y)\). \( M(x, y) \) is mean grey value and \( I(x, y) \) is grey of point \((x, y)\).

2. We assume the point to filter is an isolate noise point in smooth area. Then we get \( D(x, y) \approx |I(x, y) - I(x-1, y-1)| \). It means that \( I(x, y) \) is changed by noise.

From conditions 1 and 2, we know that \( D(x, y) \) is inverse proportion to smoothness. To consider with intensity dependent spread (IDS for short)[14], we find variance \( \sigma(x, y) = 1/I(x, y) \). Then we can calculate \( \lambda \).

When we find the proportion relation of \( \delta_{x1} \) and \( \delta_{y1} \), we define proportion R as formula (5).

\[
R = k/(k + avg(D(i, j)^2))
\]

So we find \( \delta_{y1} = R \delta_{x1} \). Moreover, \( \delta_{x2} \) and \( \delta_{y2} \) are calculated by similar steps. So we can use formula (4) to design an improved DOG filter.
PCA-LDA fusion character space. Moreover, we make mapping of training and test samples to get recognition characters. Finally, we make recognition by nearest-neighbor criterion.

So we gain our process of recognition in algorithm a and b.

Algorithm a. Training Process
Step 1. Get training sample set;
Step 2. Use improved DOG to make pretreatment;
Step 3. Construct covariance matrix;
Step 4. Solve eigenvectors’ dimension to satisfy contribution rate;
Step 5. Solve dispersion matrix in same sample class and different sample classes;
Step 6. Solve mapping matrix of LDA;
Step 7. Mapping sample average value of every class and get final sample.

Algorithm b. Recognition Process
Step 1. Get training sample set;
Step 2. Use improved DOG to make pretreatment;
Step 3. Use the same PCA as training to reduce dimensions;
Step 4. Use mapping matrix of LDA to map the image with dimensions reduced to subspace;
Step 5. Compare it with the mapping of sample by Euclidean distance to find recognition result.

IV. EXPERIMENT AND RESULT

CPU of testing PC is Intel(R) Core(TM)2 Duo CPU E7200 @ 2.53GHz, display card is ATI Radeon HD 2400 PRO and EMS memory is 1GB. OS is Microsoft Windows XP Professional (SP3) and utility software is Microsoft Visual Studio 2005. Face databases are Yale B and AR face database.

Yale B face database is a widely used to test illumination of face images. We select 10 people to be experiment objects in this paper. We choose 12 images with different illumination and angle of every object. Then we divide them to 5 subsets by angle. Angle is 10 degrees in subset 1, 20 degrees in subset 2, 40 degrees in subset 3, 60 degrees in subset 4 and 90 degrees in subset 5. In our experiment, we select 600 images to training. Every image’s size is 640×480. We select 120 images to recognize. Every image’s size is 32×38. It is shown in figure 1.

Fig.1 Yale B face database

Images in AR database are all shot by different conditions just like time, angle, expression and detail of face. In this paper, we select 50 people’s images in the experiment. We choose 8 images of every person. The 8 images are divided into 4 sets. Set a is images with normal expressions and illuminations and set b is images with different expressions and normal illuminations. The other two are with normal expressions and different illuminations. Illuminations in set c are changed by one side and set d is changed by both two sides. The number of training images is 300. We use images from 50 people and 6 images of each person. Their ids are 1, 2, 3, 5, 6 and 7. The number of testing images is 300 too. We also use 50 people and 6 images for each one. Their ids are 14, 15, 16, 18, 19 and 20. Images with id 1 and 14 belong to set a. Images with id 2, 3, 15, 16 belong to set b. Images with id 5, 6, 18, 19 belong to set c and images with id 7 and 20 belong to set d. It is shown in figure 2.

Fig.2 AR face database

Experiment. Compare with different pretreatment illumination algorithms
We test 6 algorithms in figure 3. Figure 3a is an original image, 3b is processed with HE, 3c is processed with GC, 3d is processed with DCT, 3e is processed with LCE, 3f is processed with DOG and 3g is processed with improved DOG algorithm.

Fig.3 The original image and 5 images with different processing

In order to find the best algorithm with different illumination, we use LDA algorithm to assist recognize 300 images in AR database. By test all these algorithms in recognition, we find improved DOG is the most suitable algorithm in condition with all illuminations. The test results are in table 1.

TABLE I

<table>
<thead>
<tr>
<th>Pretreatment Algorithms</th>
<th>Successful Recognition</th>
<th>Recognition Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE</td>
<td>260</td>
<td>0.867</td>
</tr>
<tr>
<td>GC</td>
<td>265</td>
<td>0.883</td>
</tr>
<tr>
<td>DCT</td>
<td>266</td>
<td>0.891</td>
</tr>
<tr>
<td>LCE</td>
<td>229</td>
<td>0.763</td>
</tr>
<tr>
<td>DOG</td>
<td>268</td>
<td>0.893</td>
</tr>
<tr>
<td>Improved DOG</td>
<td>268</td>
<td>0.895</td>
</tr>
</tbody>
</table>

Analysis of the result
Figure 3a is a dark image. Figure 3b transforms histogram to uniform distribution with stochastic distribution in figure 3a. Though the transformation
enhances distribution range of grayscales and whole luminance, it drops lots of details because of decrement of grayscale. Figure 3c is transformation by GC. It enhances luminance in dark part of original image by $\gamma>1$. But the transformation weakens several normal characters. Figure 3d is processed with DCT. It uses inverse transformation to get a new image which is similar to original image. However, it doesn’t completely improve the image’s effect because it depends on original image seriously. When we use LCE in figure 3e, we find that it shows well effect in area with many details. When we use DOG and improved DOG to transform original

<table>
<thead>
<tr>
<th>Contribution Rate(%)</th>
<th>80</th>
<th>85</th>
<th>90</th>
<th>95</th>
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</thead>
<tbody>
<tr>
<td>Character Dimension</td>
<td>21</td>
<td>80.3</td>
<td>31</td>
<td>84.6</td>
</tr>
<tr>
<td>GC</td>
<td>23</td>
<td>83.2</td>
<td>33</td>
<td>85.9</td>
</tr>
<tr>
<td>LCE</td>
<td>23</td>
<td>80</td>
<td>33</td>
<td>83.3</td>
</tr>
<tr>
<td>DOG</td>
<td>21</td>
<td>82.3</td>
<td>31</td>
<td>87.6</td>
</tr>
<tr>
<td>Improved DOG</td>
<td>22</td>
<td>83.8</td>
<td>32</td>
<td>88.9</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>TABLE III MISS RECOGNITION RADIO</th>
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<tbody>
<tr>
<td>Contribution Rate(%)</td>
</tr>
<tr>
<td>Character Dimension</td>
</tr>
<tr>
<td>HE</td>
</tr>
<tr>
<td>GC</td>
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<tr>
<td>LCE</td>
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<tr>
<td>DOG</td>
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<tr>
<td>Improved DOG</td>
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<td>GC</td>
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<td>LCE</td>
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<tr>
<td>DOG</td>
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<tr>
<td>Improved DOG</td>
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</table>

<table>
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<tr>
<th>TABLE IV RECOGNITION TIME</th>
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<tr>
<td>Contribution Rate(%)</td>
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<tr>
<td>Character Dimension</td>
</tr>
<tr>
<td>HE</td>
</tr>
<tr>
<td>GC</td>
</tr>
<tr>
<td>LCE</td>
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<tr>
<td>DOG</td>
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</tbody>
</table>
image, we find that successful recognition are better than others. It is because Gaussian filter has well effect when illumination is weak or non-uniform. To consider about practical application, DOG and improved DOG have more robustness.

Then we use table 2–4 to find the best pretreatments with PCA-LDA algorithm. We find recognition rate in table 2, miss recognition rate in table 3 and recognition time in table 4.

We can find that the improved illumination pretreatment enhances recognition rate from table 2. Furthermore, we can see our pretreatment has the best miss recognition rate from table 3. It means that the improved DOG filter makes positive effect in face recognition.

However, we should know that the improved DOG filter needs more time to design and recognize. But the waste time is fewness and character dimension do not increase much.

V. Conclusion

In this paper, we put forward an improved DOG algorithm to make illumination pretreatment. To combine with PCA-LDA reorganization method, we compare and analyze lots of characters with experiments of major illumination pretreatment algorithms. The characters contain recognition number, time, rate, miss rate and so on. From experiment results, we can see that the improved DOG algorithm is better than any other ones based on PCA-LDA algorithm when there are changes in illumination and expression of images. The disadvantage is that the improved algorithm needs more time to calculate convolution operations.

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References


Shoujia Wang, male, born in 1982, PhD, his research work include image processing and pattern recognition.
E-mail: wangsj035@163.com

Wenhui Li, corresponding author, male, born in 1961, PhD and Professor, his research work include computer graphics, computer vision, image processing and pattern recognition.
E-mail: liwh@jlu.edu