The Use of Selected Transforms to Improve the Accuracy of Face Recognition for Images with Uneven Illumination

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Abstract. This paper presents new methods of the illumination normalization in images preprocessed for face recognition system. The main problem in statistical methods of face recognition is illumination. Different lighting conditions between photos taken indoor and outdoor may drastically decrease the level of correct classification. Variations of the illumination lie mostly in low-frequency band, so it is possible to use several transforms operating on frequency domain of an image. This approach is to truncate appropriate number of coefficients in frequency domain to minimize variations under different lighting conditions. This paper presents methods using transforms such as: Two Dimensional Discrete Cosine Transform type II (2D-DCT-II) and two Periodic Piecewise-Linear Transforms, such as: Periodic Haar piecewise Linear Transform (PHL) and Periodic Walsh piecewise-Linear Transform PWL. The main advantage of this approach is that, it does not require any modeling steps and it can be implemented in real-time face recognition systems.

Keywords: Discrete Transforms, Discrete Cosine Transform, DCT, Periodic Walsh piecewise Linear Transform, PWL, Periodic Haar piecewise Linear Transform, PHL, Image preprocessing, Face recognition, Illumination reduction, Illumination normalization.

1 Introduction

Variable illumination is one of the most important problems in face recognition. Lighting condition change between indoor and outdoor environments, so one of main aims for face recognition researchers in wise understood computer vision is to create face recognition system insensitive for illumination changing.

L. Atzori, J. Delgado, and D. Giusto (Eds.): MOBIMEDIA 2011, LNICST 79, pp. 242–251, 2012.

The article deals with spectral analysis of an image, so all modifications are done on the transformed image into the frequency domain. The approach presented in this paper can be presented in the following three steps:

- Image values normalization;
- Transformation of image into logarithm and frequency domain and truncation appropriate number of coefficients;
- Computing the inverse transform and truncate a histogram of an image.

2 Image Values Normalization

Four following steps in normalization process could be distinguished:

- Subtraction the minimal value of an image from all pixels;
- Computing the difference between minimum and maximum value of an image;
- Computing the division of results of step I and II;
- Multiplication results of step III by 255.

To normalize an image, it is necessary to compute the minimal value of the whole image. Then subtract this value from all pixels. This operation leads to obtain '0' as a minimal value in whole image.

Next, it is necessary to compute value compound of subtraction maximum and minimum value of the whole image. Then, divide the results of both steps: I and II.

The last step is just to multiply the results of the second step by 255. It is necessary to get images normalized. The new image contains values between 0 and 255. All these operations can be represented by the following formula:

$$[IMG_{norm}] = \frac{[IMG] - [IMG_{min}]}{[IMG_{max}] - [IMG_{min}]} * 255 \tag{1}$$

Where,
$[IMG]$ represents an image matrix
$[IMG_{min}]$ represents a matrix, which has the same size as an image matrix and all values of this matrix are equal to the minimum value of an image matrix.
$[IMG_{max}]$ represents a matrix, which has the same size as an image matrix and all values of this matrix are equal to the maximum value of an image matrix.
$[IMG_{norm}]$ represents a normalized image matrix.

3 Discrete Transforms

In this section, all used transforms will be presented in detail: DCT, PHL and PWL.

3.1 Discrete Cosine Transform (DCT)

DCT is a Fourier related transform, similar to Discrete Fourier Transform.

There are eight types of this transform. The most common is type II, which is described by equation 2.

$$X_{DCT}(k,l)=\sum_{m=0}^{M-1}\left[\sum_{n=0}^{N-1}x(m,n)\beta(l)\cos\left(\frac{\pi l}{N}(n+\frac{1}{2}\right)\right]\alpha(k)\cos\left(\frac{\pi k}{M}(m+\frac{1}{2}\right) \quad (2)$$

Where,

m, n represent rows and columns of image.

$$\alpha(k)=\begin{cases}\sqrt{\frac{1}{M}}, k=0\\ \sqrt{\frac{2}{M}}, \quad k=1\ldots M-1\end{cases} \quad (3)$$

$$\beta(l)=\begin{cases}\sqrt{\frac{1}{N}}, \quad l=0\\ \sqrt{\frac{2}{N}}, \quad l=1\ldots N-1\end{cases} \quad (4)$$

The Two Dimensional Cosine Transform – II is a compound of two series one-dimensional cosine transform [2][3][4].

3.2 Periodic Walsh piecewise-Linear Transform (PWL)

The Periodic Walsh piecewise-Linear PWL functions, which are the basis functions of the PWL transform, are obtained by integrating periodic Walsh functions as follows [4][5]:

$$PWL(0,t)=1, \qquad t\in(-\infty,+\infty) \quad (5)$$

$$PWL(i,t)=\frac{2^{k+1}}{T}\int_{mT}^{t+mT}Wal(i,\tau)d\tau \quad (6)$$

Where $i=1,2,\ldots,N-1$, $k=1,2,\ldots,\log_2 N$, $m=0,1,2,\ldots$,k is the group index of PWL functions and m is the number of period.

The matrix form of the forward and inverse PWL transforms may be formulated as follows:

Forward transform: $[C(N)=\left[-2^{-(k+1)}\right][PWL(N)][X(N)]$ (7)

Inverse transform: $[X(N)]=[IPWL(N)][C(N)]$ (8)

Where:

[C(N)] is a vector of PWL coefficients;
[X(N)] is a vector of sampled signal;
[PWL(N)] is a matrix of forward transform;
[IPWL(N)] is a matrix of inverse transform;
[-2-(k+1)] is a diagonal matrix of normalization.

3.3 Periodic Haar piecewise Linear Transform (PHL)

The set of Periodic Haar piecewise-Linear (PHL) functions [5] is obtained by integrating the well-known set of Haar functions. The set of PHL functions is defined by:

$$PHL(0,t) = 1, \qquad t \in (-\infty, +\infty) \tag{9}$$

$$PHL(1,t) = \left[\frac{2}{T}\int_{mT}^{t+mT} Har(i,\tau)d\tau\right] + \frac{1}{2} \tag{10}$$

$$PHL(i+1,t) = \frac{2^{k+1}}{T}\int_{mT}^{t+mT} Har(i+1,\tau)d\tau \tag{11}$$

Where $i = 1, 2, \dots, N-2$, $k = 1, 2, \dots, (\log_2 N) - 1$, $m = 0, 1, 2, \dots$,k is the group index of PWL functions and m is the number of period. The matrix form of the forward and inverse PWL transforms may be formulated as follows:

Forward transform: $$[C(N) = \left[\frac{-1}{2^{-(k+1)}}\right][PHL(N)][X(N)] \tag{12}$$

Inverse transform: $$[X(N)] = [IPHL(N)][C(N)] \tag{13}$$

Where,

[C(N)] is a vector of PWL coefficients;
[X(N)] is a vector of sampled signal;
[PHL(N)] is a matrix of forward transform;
[IPHL(N)] is a matrix of inverse transform;
$[\frac{-1}{2^{-(k+1)}}]$ is a diagonal matrix of normalization.

4 Algorithm of Normalization

The normalization process described in this section bases on the approach presented in [9][10] allows reducing the shadow effect.

Figure 1 presents an example image, where half of the face is covered by the shadow, whilst Figures 2,3,4 present results of transforms: PHL, DCT, PWL made on the example image.

Fig. 1. The example image, where half of the face is covered by the shadow

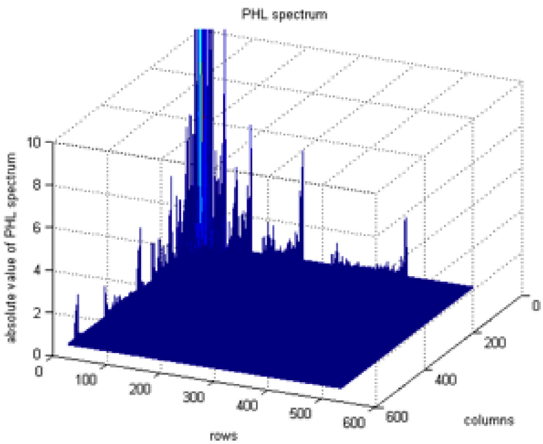

Fig. 2. Spectrum of Periodic Haar Piecewise-Linear Transform (PHL)

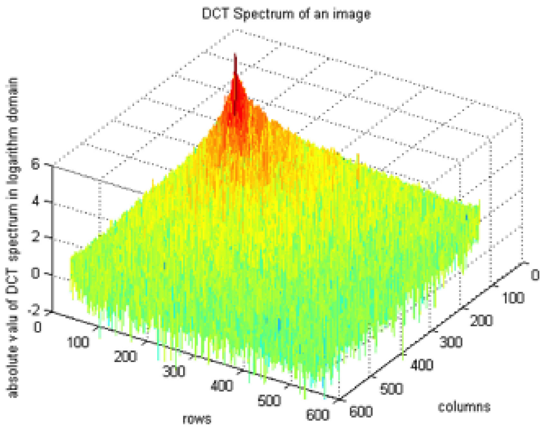

Fig. 3. Spectrum of Two Dimensional Discrete Cosine Transform (DCT)

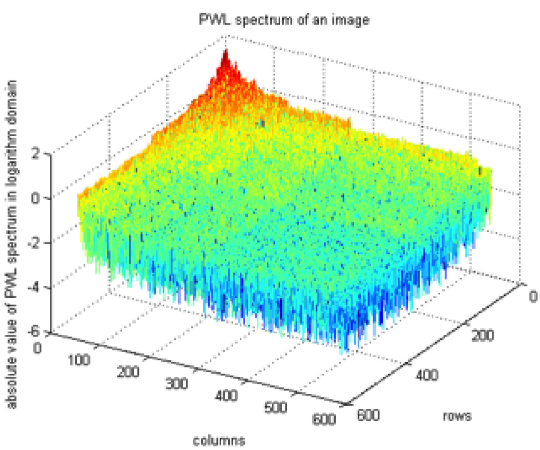

Fig. 4. Spectrum of Periodic Walsh Piecewise-Linear Transform (PWL)

It is easy to see that the most significant coefficients are placed in the upper corner. All values quickly diminish with the distance from the corner. This fact concerns all presented types of transforms.

Three discrete transforms can be used in presented algorithm. The Discrete Cosine Transform is popular and commonly used in many cases, also in illumination reduction algorithms.. However Periodic Walsh Piecewise-Linear Transform and Periodic Haar Piecewise-Linear Transform have been never us in such case. Illumination reduction is a new issue where these two transforms can be implemented.

It is possible to specify some steps in algorithm of illumination reduction:

Step 1. The first step of the normalization process is to read consecutive coefficients in specific way [7][8].

Approach presented in Figure 5 shows the way to read particular coefficients of an image. It is necessary to start reading coefficients from the biggest to the smallest. Starting reading in the left upper corner allows obtaining firstly the most significant coefficients. Smaller (low-frequency) values will be read after bigger (high-frequency) values of the transform. Discarding the low- frequency transform's coefficients in the logarithm domain is identical to compensate the illumination variations.

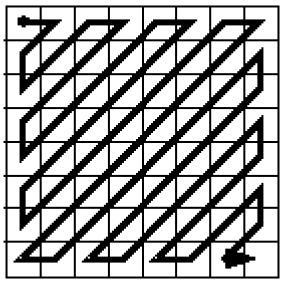

Fig. 5. Scheme how to read transform's coefficients (zigzag scan)

Step 2. The first coefficient describes overall illumination of an image. It is worth to change it in specific way. Firstly the average value of the image in gray scale must be computed. Then logarithm of the average value must be multiplied by a square root of amount of all pixels in the image.

All this computation could be presented by a given equation:

$$IMG(1,1) = \log(\alpha) \cdot \sqrt{M \cdot N} \tag{14}$$

Where α is an average level of gray scale of an image, M and N describe size of an image.

Step 3. The last proposed step is to change values to zero of some low-frequency coefficients, which are also strongly connected with illumination [1][2].

A particular image determines how many coefficients should be changed to zero value. It depends on quality of an image, resolution, etc.

5 Results

Figure 6 presents example of results of all described methods in this paper. In the figure 6a) there is presented original image where half of the face is covered in the shadow. Figures 6b), 6c), 6d) present results of illumination reduction.

Fig. 6. a) original image, b) normalization using DCT, c) normalization using PHL, d) normalization using PWL

Presented methods are appropriate to decrease differences between indoor and outdoor light conditions.

Figure 7 presents another example of results. A problem presented in the Figure 7a) is dark image. Figures 7b), 7c), 7d) present results of using described transforms.

As it is presented in the Figure 7d) *Periodic Walsh Piecewise-Linear Transform* gives better results than well-known *Two Dimensional Discrete Cosine Transform*.

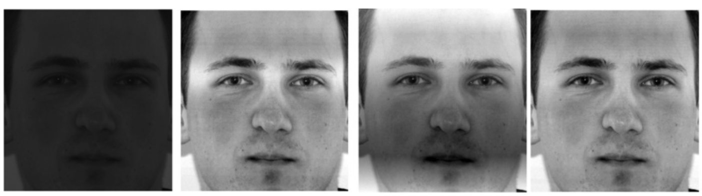

Fig. 7. a) original image, b) normalization using DCT, c) normalization using PHL, d) normalization using PWL

Results of Illumination Reduction Algorithm in Face Recognition System

Article [6] presents works about statistical face recognition algorithms.

Tests described in [6] were repeated with illumination reduction algorithm. Tests consider two statistical algorithms Principle Component Analysis and Linear Discriminant Analysis and also a special fusion of these two algorithms presented in [6].

Following tests were carried out and described in this article:

- Single classifier (without normalization)
- Fusion of LDA & PCA (without normalization)
- Single classifier (normalization)
- Fusion of LDA & PCA (without normalization)

Tables 1-3 present results of correct classification in face recognition system. Tests were done on AT&T database. Data set was not divided in any subsets.

The column “First Place” describes the percentage of correct classification in particular algorithms in the way that correct person was in the nearest image, whilst the column “First Six Places” describes the percentage of correct classification in a particular algorithm in way that correct person was in one of six nearest images.

Tests prove that in this case PWL transform method gives better results than DCT method.

It must be noticed that results depends on database and it is possible that in different data base other transform e.g. PHL transform gives better results.

Table 1. Results of correct classification in face recognition system (PWL transform)

	Single classifier without normalization		Fusion of LDA & PCA without normalization	Single classifier with normalization		Fusion of LDA & PCA without normalization
	PCA	LDA	PCA & LDA	PCA	LDA	PCA & LDA
First Place	80,25%	82%	86%	82.75%	84.75%	88,25%
First six places	89%	90,25%	91,25%	91%	92,25%	93%

Table 2. Results of correct classification in face recognition system (DCT transform)

	Single classifier without normalization		Fusion of LDA & PCA without normalization	Single classifier with normalization		Fusion of LDA & PCA without normalization
	PCA	LDA	PCA & LDA	PCA	LDA	PCA & LDA
First Place	80,25%	82%	86%	82.5%	84%	87,25%
First six places	89%	90,25%	91,25%	90,75%	91,75%	92%

Table 3. Results of correct classification in face recognition system (PHL transform)

	Single classifier without normalization		Fusion of LDA & PCA without normalization	Single classifier with normalization		Fusion of LDA & PCA without normalization
	PCA	LDA	PCA & LDA	PCA	LDA	PCA & LDA
First Place	80,25%	82%	86%	79%	80%	81%
First six places	89%	90,25%	91,25%	83%	83,5%	85%

6 Conclusions

The aim of works was to examine commonly used algorithms of reduction of the illumination influence and try to implements new methods of illumination reduction for face recognition systems.

Three methods, presented in the article, which use transforms such as: Two Dimensional Discrete Cosine Transform type II (2D-DCT-II) and Periodic Piecewise-Linear Transforms: Periodic Haar piecewise Linear Transform (PHL) and Periodic Walsh piecewise-Linear Transform (PWL) were implemented and tested.

To compare this works to other i.e. article [1] it is worth to notice this article describes spectral modifications of an image, but using only Discrete Cosine Transform. Article [2] is a comparative study among several preprocessing algorithms, but the idea of using Periodic Haar piecewise Linear Transform (PHL) and Periodic Walsh piecewise-Linear Transform (PWL), presented in this article is new.

Tests prove that the use of PHL and PWL transforms gives better results than 2D-DCT in many cases. The tests are fully reproducible.

Methods presented in the article can be used as a powerful addition to face recognition systems. It is worth to add that presented algorithms are fast, so presented methods are implemented in real-time face recognition system.

The plans for future are to integrate these normalization methods with race recognition system to increase the level of correct classification.

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