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A Hybrid Approach to normalize the light illumination in facial images using DCT and Gamma Transformations

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Abstract: In this paper we propose a hybrid approach to normalize the illumination intensity in facial images using Discrete Cosine Transform (DCT) and gamma transformation. The image is transformed into frequency domain using DCT and the proposed method is used to get the areas affected by illumination. Those areas are normalized using power law transformation, using the gamma value found by the method. The experiment is done on the Yale B database and the results show an improvement in extracting edges from faces due to illumination normalization.

Keywords: DCT, gamma transformation, illumination separation, region based separation)

I. Introduction

Over the last two decades, the research in the field of image processing has undergone an exponential growth with the ability to solve real world problems. That may include tracking down a vehicle in an image, face tracking using facial recognition, satellite image processing, and authentication in applications such as debit/credit cards, passports, voter ID etc. Among them there are many applications which use the image of the user as the input and perform various operations on them. This includes face identification, emotion detection, age estimation etc. In all these applications, the input is a face image. Processing facial images taken in an outdoor environment with variation in expression and illuminations are difficult.

In previous works, the images were represented using edge maps, filters (Gaussian, Sobel, canny etc.), first or second derivatives and logarithmic transforms. But none of them were able to overcome the problem with the variation in illumination on the subject.

II. Earlier Works

A lot of work has been done for image enhancement by Vimal et al. [1]. They introduced an approach for finding gamma value. The calculation is based on the histogram peak value, which gives the details about the background color. This method works well for images, where background and foreground peaks are not well separated, i.e. the input image is of low contrast. But for the images with high contrast (a wide separation of foreground and background peaks), the method is not so effective. Michelle M. Mendonca et al. [2] showed an effective method for face recognition. It includes Log Transformation, Homomorphic filtering and Wavelets. Then face recognition is done using Principal Component Analysis (PCA). Of these three methods, it is found out that the wavelet method is very effective because the face image resulting from wavelet process enhances the edges and provide other details that facilitate further face identification process. S Venkatesan et al. [3] investigated the same idea described by Michelle M Mendoca et al. They used genetic algorithm instead of PCA for the recognition process. Shan et al. [4] investigated several illumination normalization methods and proposed Gamma Intensity Correction (GIC), Region-based strategy combining GIC with Histogram Equalization and Quotient Illumination Relighting (QIR) method. It is found that QIR is a better solution and that can estimate the lighting modes of an image. Ching Chung Huang et al. [5] proposed an algorithm that uses Homomorphic filtering. In this method, the face will be divided vertically and horizontally into equal halves. Then, Homomorphic filtering is done on those sub images and merged once again (two horizontal halves together and two vertical halves together, then they are merged together). Then an illumination reference model is constructed from the input face image and it is used to adjust the illumination. The combination of modified illumination information and facial feature is used to get normalized face image. Virendra P. Vishwakarma et al. [6] showed the usage of DCT to find the illumination of the image using the DC and AC coefficients. The image is then rescaled to lower frequency DC coefficients to get the image normalized. The operation is done on the full image. This is a modified version of the work by W. Chen et al. [7].

III. Algorithm Description

A. Histogram Equalization

It is a process of enhancing the contrast of an image using its histogram. The histogram of the digital image of gray scale value (range 0 to (L-1)) is defined by the discrete function

$$p(r_k) = n_k/n \quad (1)$$

Basically $p(r_k)$ is the probability of occurrence of each gray level in the image. Through this technique, the intensity is distributed over the entire image. Histogram equalization is defined as the transformation of input intensity levels (r_k) into output intensity levels (s_k) as

$$s_k = T(r_k) = \sum_{j=1}^k p(r_j) = \sum_{j=1}^k \frac{n_j}{n} \quad (2)$$

for $k = 1$ to L

Figure 1: Histogram Equalisation (Left Side : Original Image, Right Side : Histogram equalized image)



B. Adaptive Histogram Equalization

For images, which contain local regions with low contrast bright and dark regions, histogram equalization will not work globally. So we can use adaptive histogram equalization (AHE) for those images. Adaptive Histogram Equalization works by considering only small regions and based on their cumulative distribution function values, performs contrast expansion on these regions. So we can use this method for the facial images which are dark, where we can't see the features like edges clearly. The image in fig 2 shows the use of this method. We can observe that the first face is considerably darker and features like nose, mouth and eyes are not clear. But after adaptive histogram equalization, we can observe their face parts more easily. As we can see, AHE does not influence the variation in the illumination. We can still use this to rebuild the image after finding the regions affected by the illumination. We will use DCT and their coefficients to find the illuminated regions.

Figure 1: Output of AHE (a-input image, b-AHE output)



C. Discrete Cosine Transformation

It is a popular technique in imaging and video compression. It converts the signals from spatial domain to the frequency domain. It has the property that most significant features of an image are concentrated in the few coefficients of the DCT. So it forms the major for lossy image compression algorithm known as JPEG (Joint Photographic Experts Group). The forward 2D DCT of an $M \times N$ block image is given by

$$C(u, v) = \alpha(u) \alpha(v) \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y) X \cos\left(\frac{\pi(2x+1)u}{2M}\right) \cos\left(\frac{\pi(2y+1)v}{2N}\right) \quad (3)$$

The inverse transform is defined as

$$f(x, y) = \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} \alpha(u) \alpha(v) C(u, v) X \cos\left(\frac{\pi(2x+1)u}{2M}\right) \cos\left(\frac{\pi(2y+1)v}{2N}\right) \quad (4)$$

where

$$s = c * r^\gamma \quad (7)$$

In [1], Vimal et al. showed that maximum contrast stretching occurs by choosing the value of γ for which the transformation function has the maximum slope at $r=r_{max}$. That is, if m is the slope of the transformation, then γ should produce output which is produced when $r = r_{max}$. So, he found out the formula for γ as follows,

$$\gamma = -\frac{1}{\ln(\frac{r_{max}}{L-1})} \quad (8)$$

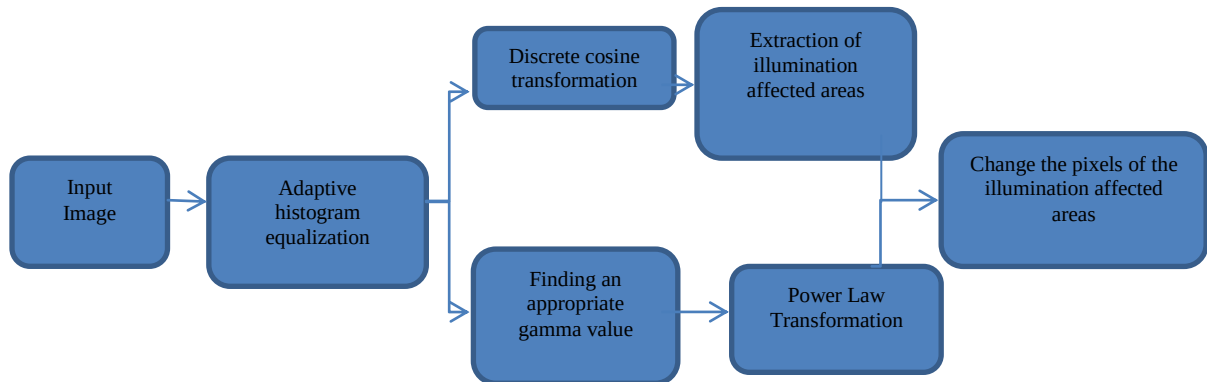
IV. Experimental Results and Discussion

The Fig 5 shows the flow of our approach. Our approach involves two major changes from the available methods. First step is finding the regions affected by the illumination from the input image. Second step is to adjust the illumination of these regions by finding the appropriate gamma for power law transformation.

A. Face Database

The experiment is done on the Yale B database which contains the image of 10 subjects each seen under 9 poses and 64 illumination types from different angles. In our approach, the concept is concentrated on the cropped face of those subjects.

Figure 4: Proposed Approach



B. Adaptive Histogram Equalization

This is the first step in our process. The input image is subjected to adaptive histogram equalization. Fig 2 shows the output of the adaptive histogram equalization.

C. Discrete Cosine Transformation

The modified version [6] of the method, which is mentioned in [7], shows the promising measure to take care of the illumination in the face. But it is seen that output given by [6] result has less brightness, thus reducing the details of the face. Fig 6 shows that the above conclusion is true. In [6], they rescaled the DC coefficients of low frequency and divided them by 50. This is done because the illumination variations are directly related to the low-frequency DC coefficients. To deal with the problem mentioned above, we will multiply the constant 5 with the DC coefficients. Then IDCT is performed with the modified coefficients. Now this IDCT will give the image which represents the regions with illumination variance. This can be seen in Fig 7.

Figure 5: Output of the method proposed in [6] with the brightness of the image affected

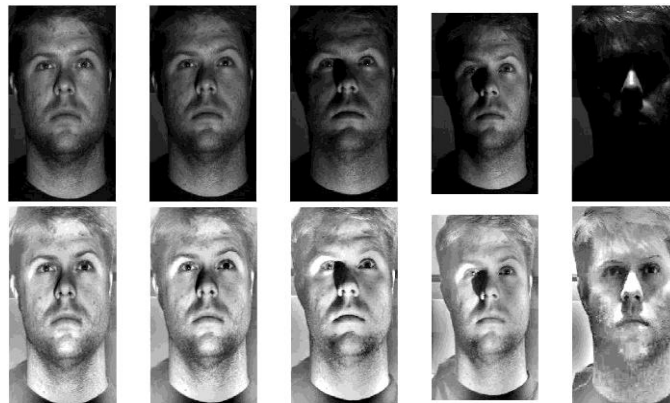


Figure 6: AHE output and IDCT output after multiplying DCT coefficients with the constant 5



D. Power Law Transformation

Using the formula proposed in [1] for some gamma values it is observed that there is too much brightness or too little brightness. So in our approach, we set a constraint for the gamma values. Thus the intensity of the image is preserved with the appropriate gamma values. The condition is as follows

```
IF Gamma > 5 THEN
    Gamma = 5
ELSE IF Gamma < 1 THEN
    Gamma = 1.02
END IF
```

These ranges are set based on the observation from Fig. 4. With gamma greater than 5, there will be little brightness and too much brightness for gamma value less than 1.

E. Final Step

From the previous steps we have got the regions of the image affected by poor or too much illumination and a good gamma value for correcting that illumination. With this gamma value, we perform power law transformation on the original image (image 'O') and let the output of this transform be image 'A'. Let the output of IDCT of DCT coefficients multiplied by 5 be image 'B' as shown in Fig 7. Now the output 'R' can be obtained by the following procedure. The pixel positions are indicated by (i, j) where 'i' is the row and 'j' is the column.

```
FOR ALL PIXELS IN THE IMAGE
    IF B(i,j) == WHITE THEN
        R(i,j) = O(i,j)
    ELSE
        R(i,j) = A(i,j)
    END IF
END FOR
```

Now the output is shown in Fig 8. We can see that, the brightness of the input image is preserved and the necessary regions are modified correctly. The intermediate outputs are shown in figure 9.

Figure 7: Output of proposed method



Figure 8: Output during intermediate steps



F. Discussion

To test this approach, we used this as a pre-processing step in the project – Age estimation using facial images. Fig. 10 and Fig. 11 shows that the result of applying enhanced canny edge detector on an illumination corrected image is better than the result obtained by directly applying the edge detector on the subject image. Enhanced canny edge detector is applied on these images to extract wrinkles.

Figure 9: Comparison of performance of edge detectors before and applying using illumination normalization on the image of person (age 22). Image Source: FGnet Database

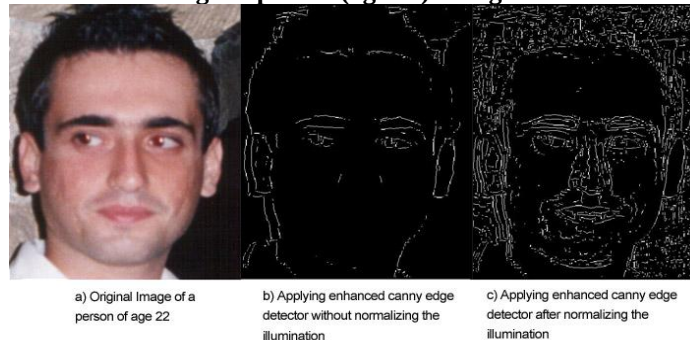
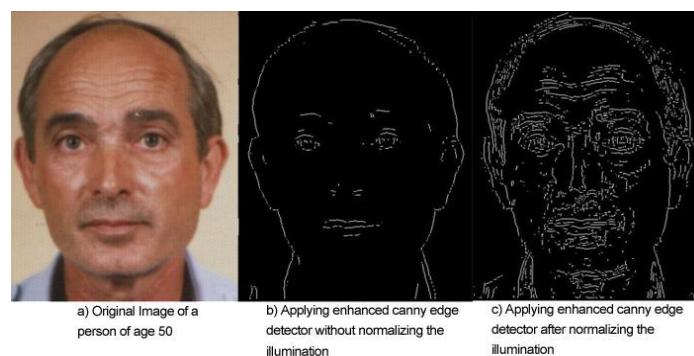


Figure 10 Comparison of performance of edge detectors before and applying using illumination normalization on the image of person (age 50). Image Source: FGnet Database



V. Conclusion

In this paper, we propose a hybrid approach to normalize the illumination in facial images using DCT and power law transformation. The modified DCT method is used to extract the regions which are affected by illumination. Then power law transformation with appropriate gamma value is used in image enhancement. Unlike many other methods, in our method, the regions which don't need illumination correction will never be modified.

VI. References

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