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Binary conversion method based on illumination distribution model under unconstrained smartphone face database

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Abstract

One of the most important methods to extract unique features for distinguished several classes in face recognition is by generating a binary image from the original image, which is then used as input in the feature extraction process. In face recognition scenario, illumination variation is a challenging problem due to the dramatically changes of face appearance depending on the illumination conditions. It has a major effect on the clarity of binary image, where most of the binary image conversion methods had failed under the effect of these conditions. Therefore, to deal with this problem effectively, a model of illumination distribution over a whole image is proposed, this model is based on the polynomial function and it is used as an input for proposed binary conversion method which starts by calculating an adaptive threshold value depending on the illumination model and converts the image by comparing each column pixels individually with the adaptive threshold value. The proposed method works by making evaluation on smartphone face video dataset and comparing with the Global image threshold using Otsu's method. The experimental results showed the outperformance of proposed method.

Keywords: **face recognition, smartphone, illumination variation, binary conversion.**

1. Introduction

Over the last few decades, there is an increasing interest in regards to face recognition studies among researchers due to its various applications in many fields including law and security, in addition to those that require image understanding. Most face recognition methods were initially developed with face images collected under relatively well controlled conditions, and in practise it is difficult to deal with the range of appearance variations that commonly occur in unconstrained natural images due to illumination, pose, facial expression, ageing, partial occlusions, etc [1].

Among all the challenges in face recognition system, illumination variation in face images demonstrates a crucial problem that reduces the accuracy of recognition system [2]. Furthermore, a study had supported that illumination variation has been known to be one of the major challenges for current face recognition system since facial feature appearance strongly depends on ambient lighting [3]. Changes in the level of light intensity or the direction of light source, is a challenging problem in which researchers have focused their efforts through various approaches [4,5].

Generally, there are three classes of traditional approaches that can be used to cater to this problem, which are appearance-based, normalisation-based and feature-based methods. Although there were many previous researches which were based on these classes, but most of these methods still face some problems under the extreme illumination variation environments [1].

This paper focuses mainly on the issue of robustness to lighting variations. For example, a face verification system should be able to verify a client at any time (day or night) and in any place (indoors or outdoors). Therefore, this study proposed an integrative framework combining the strength of the appearance-based and normalisation-based approaches to generate a model representing the illumination distribution over whole image resulted from different lighting source directions. In addition, the illumination distribution model coefficient was used as a factor to set an appropriate threshold value in converting the original image to binary form. This is because binary image was used as an input to feature extraction process with an important role in generating unique feature to distinguish several classes of pattern recognition [6]. Based from the findings, the proposed method demonstrated the potential in a wide range visual feature sets by eliminating various effects of changing illumination, while preserving most of the appearance details from the original image.

Thresholding method is among the most commonly used binary conversion methods to date. There are generally two types of thresholding method; global thresholding and local thresholding method. The first method, which is global thresholding is a simple method that can be easily applied and also fast in operating due to fewer computations required. However, it failed under variation illumination conditions. On the other hand, local thresholding method segments an entire image into sub segments with a specific threshold in each small segment. Implementing this method is difficult since it is slow and complex. Although this method is used in ununiformed illumination environment, it is still inefficient for images with high illumination variation [7]. Therefore, this study proposed a novel and robust method to calculate a threshold value under illumination variation conditions that ensure the appearance of distinguished face feature.

The main contribution of this study is in generating a model for illumination distribution over a whole image using polynomial function based on index pixel value of special region within the image. Moreover, a new binary conversion method was proposed using this threshold to effectively convert the image into binary. The results of the proposed method showed an enhanced appearance of facial features such as eyes, eyebrows, nose and mouth compared to that of global Otsu's thresholding method.

2. Literature Review

Binary image is an excellent idea to preserve face features, as it plays an important role in generating unique features to distinguish several classes in pattern recognition apart from being used as an input to feature extraction process [6]. Thresholding algorithms are among the most common methods used in binary conversion, which have been discussed by many researchers regarding their effects on threshold algorithms and their major role in threshold value computing process [8]. Previously, many studies have been carried out using several techniques for computing the adaptive thresholding value based on illumination variation. In a study, the threshold was computed according to contrast using the local mean and standard deviation of the neighbouring pixels inside a local window [9]. Moreover, a technique known as local grey range technique was introduced to identify the threshold value inside the range between the maximum and minimum pixels, with the use of grey range within the local window [10]. In a more recent study, the local adaptive threshold was computed using a technique obtaining different results based on their calculation process [11]. It was observed that the contrast in the local neighbourhood was quite low, leading to a smaller threshold as compared to the mean value. Hence, confirming the success of this technique in removing the relatively dark regions of the background.

Iterative Region based Otsu (IRO) thresholding was proposed as an improvement for the Otsu's [12], and in another study where iterative Otsu's threshold method was introduced in variation illumination environment [13]. The IRO method computed the threshold value using the statistics of greyscale intensities and regional distribution of the illumination noise. However, it was seen that the IRO method did not perform well with the shaded region.

A previous study had proposed to use an adaptive thresholding because it takes into account spatial variations in illumination [14]. Adaptive threshold compares a pixel to the average of nearby pixels to preserve hard contrast lines and ignore soft gradient changes. [15; 16] proposed to increase robustness of adaptive threshold method to strong illumination changes by using integral images. The main drawback of this method is that the images have to be processed twice which increases the implementation time.

Based from the literature, it can be summarised that there is lack of study which focuses on the effect of different directions of lighting source on the illumination distribution over the whole image affecting the appearance of the image regions and on image details. Therefore, this study had collected the proposed smartphone video dataset with no specific conditions, which included different environment with different lighting directions depending on sunlight or room light direction during the recording time. Moreover, an adaptive threshold was generated to overcome the affection of illumination variation on the appearance of face features in binary image, which was calculated according to the proposed illumination distribution model.

3. PROPOSED METHOD

This study proposed a novel method that enhances the effects of variation of illuminance distribution that resulted from different directions of the light source spread over the whole image. A successive binary conversion method was proposed based on the illuminance distribution modelling. Meanwhile, the variation illumination distribution that comes from different directions of lighting sources will affect the performance of the face recognition algorithm. To reduce the effect of this problem, a model for variation illumination distribution over the whole image was introduced. Figure 1 shows the framework of the proposed method that starts with extracting the video frames and converting the RGB frames to greyscale, followed by index image in order to facilitate the subsequent steps.

3.1 Illumination Distribution Model

It is well known that when the light sources come from different directions on the face, the luminance distribution across the face is unequal, which affects the feature detection methodology [21]. Therefore, to overcome this problem, an illumination distribution model was proposed to clarify as much important face features as possible in the binary image by generating an adaptive threshold for binary image conversion operation.

The modelling of illumination requires the investigation on the possibility of using mathematical functions as successful models. The polynomial function was used by this study to get the good fit for the variation of illumination distribution. This model requires some known intensity values of known points in the space. In order to find these values, this study had identified a reference horizontal line from the image and obtained the index value for the pixels of this line.

In choosing a suitable reference line, a variance experiments were concluded by scanning the reference horizontal line in different places of image. The experimental results had showed that the most suitable region for choosing the reference line is the forehead area of the face. This is because other face regions have a peak and hall that will lead to a strong variation in the index value, which is not exactly related to the illumination distribution variations.

From the index values of the reference line pixels, the model obtained its values and returned the coefficients for a polynomial of second order that is a best fit (in a least-squares sense) to the data of the reference line as in Equation (1).

$$p = polyfit\ (1{:}row, ind(ref), n) \qquad (1)$$

Where n is the polynomial order and P=Coefficients is a matrix of (1, n+1).

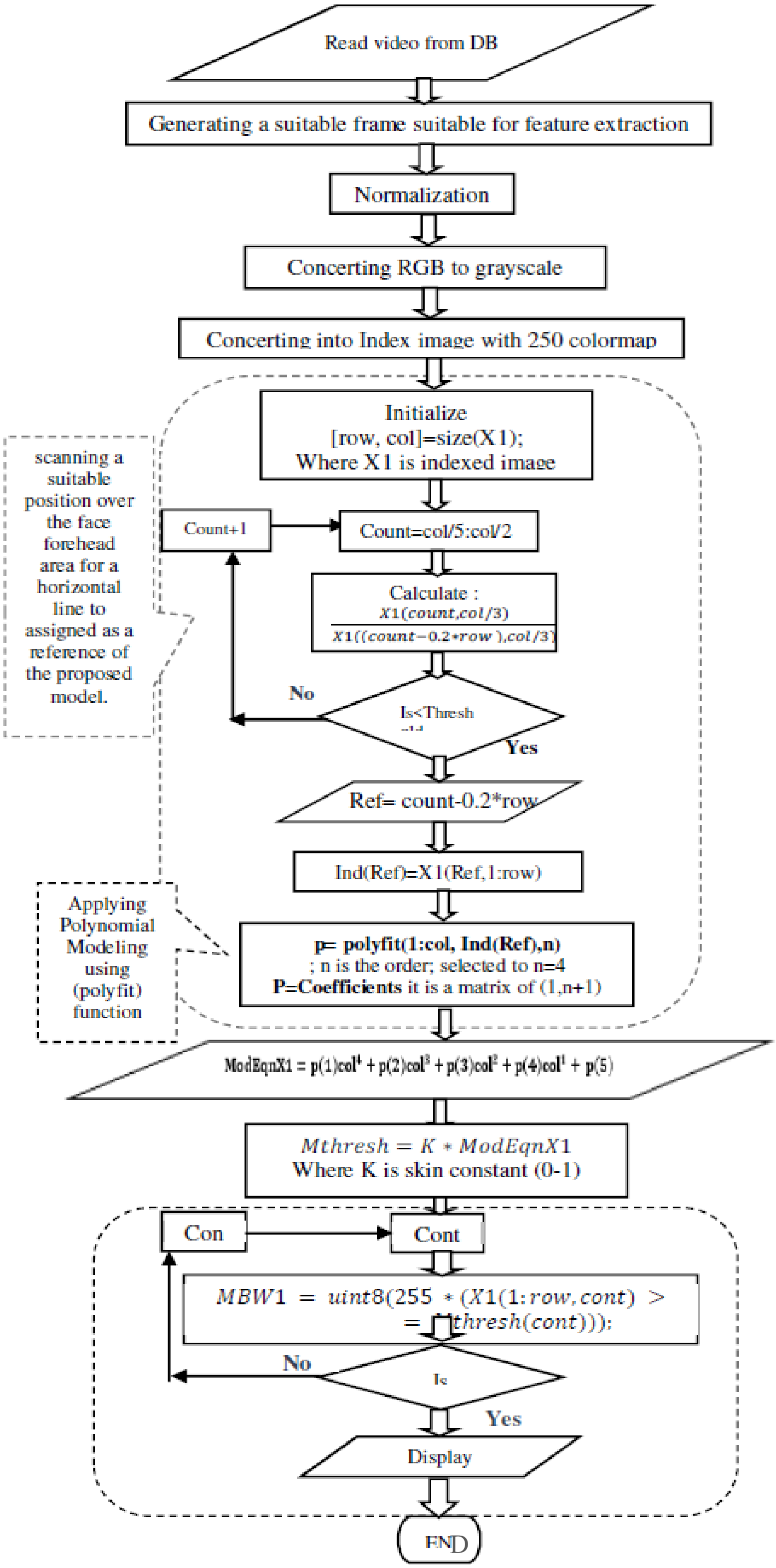

Figure 1: Proposed Method Framework

The coefficient value identified from Equation [2] gives a good fitting for the illumination variation that can help the adaptive thresholding generation operation.

$$ModEqnX1 = p(1)col^4 + p(2)col^3 + p(3)col^2 + p(4)col^1 + p(5) \quad (2)$$

$ModEqnX1$ is the coefficient value of the illumination distribution model.

3.2 Binary Conversion Method Based on Luminance Distribution Modelling

The illumination variations on faces degrade not only on the face detection accuracy, but also the face feature matching performance. This is due to the difficulty of extracting good features under severe illumination variations. In addition, the variation of illumination distribution will hide some parts of the face because of specific face structures (the peak and halls between face regions).

The binary image helps the feature extraction operation since it clarifies the distinguished region of face (the eye, eyebrow and mouth). The variation in illumination distribution has different effects on the binary image clarity. It can turn some parts of an image to become darker or hide some regions, thus affecting the identification of the best face feature.

In order to overcome this problem and enhance the binary conversion method, an efficient binary conversion method was produced based on the coefficient of the illumination distribution model to find the adaptive threshold value. The proposed method calculated the adaptive threshold value based on Equation [3] that multiplies the coefficient value of the polynomial illumination distribution model by constant value (K).

$$Mthresh = K * ModEqnX1 \quad (3)$$

Where K is skin constant (0-1).

In the proposed binary conversion method, each column pixels was compared individually with the threshold value and the pixels with a bigger value than the proposed threshold ($Mthresh$) is considered to be acceptable.

4. Data Set (Smartphone Face Video Database)

The proposed method was evaluated on unconstrained smartphone videos database that was used in this study. It contained 200 videos for 50 subjects. The videos were recorded from two cameras of iPhone 6 (rear and front camera) in different lighting conditions (different room), lighting (yellow light, white light), sunlight and from different directions (randomly direction) and two environments (indoor and outdoor) with different background (room, restaurant, office, garden and street). In addition, these videos were captured from different distances depending on the subjects' arm length especially for front camera (the same concept of selfie). The videos were recorded on different days with no rules imposed on the subjects in terms of direction of set and colours of clothings.

5. The Experimental Results

The proposed successive binary conversion processing based on luminance distribution modelling method was evaluated by a series of experiments using smartphone dataset of this study. All videos frames were resized to [1200 x 700]. The method in MATLAB ® release R2013b was implemented in this study. The efficacy of the proposed method was measured on the test dataset, which are 200 iphone6 videos. The performance of the proposed scheme was evaluated in terms of similarity measure using Root Mean Square Error (RMSE).

The performance of the proposed method of binary conversion using adaptive threshold value which was calculated based on the coefficient of the illumination distribution model was seen as comparable to that of Global image threshold using Otsu's method. The Otsu's method does not work if there are large variance in illumination. Figure 2 shows the comparison results based on the RMSE. The lower RMSE values refers to the similarity of the obtained image with the ground truth.

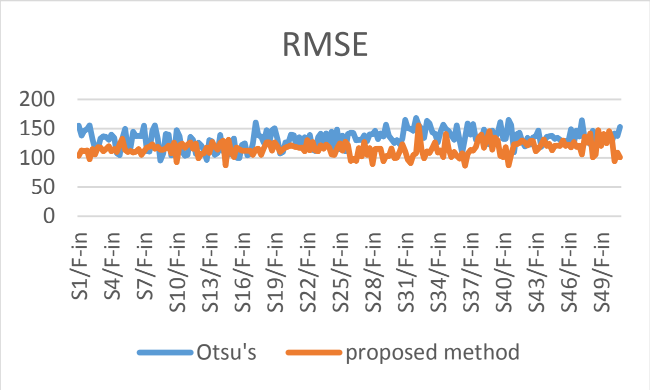

Fig.2: The comparison results based on the RMSE.

Finally, it can be observed from the results that the proposed binary conversion method is better than the Global image threshold using Otsu's method as it as it preserved the appearance of most important face features under illumination variation conditions. Figure 3 illustrates the results of the proposed method compared to that of Otsu's method.

a

b

Fig.3: a. the original video frame. b. the results of Global image threshold using Otsu's method. C. the results of our proposed binary conversion method.

6. Conclusion

Binary image is one of the substantial techniques to extract unique features for several distinguished classes in face recognition, which are used as input in feature extraction process. Face appearance is greatly affected by illumination variation. Moreover, it has a major effect on the clarity of binary image. Most of the binary image conversion methods failed under the effect of various illumination conditions. Hence, to overcome this problem effectively, a model of illumination distribution over a whole image is proposed, this model is based on the polynomial function and it is used as an input for proposed binary conversion method. The proposed method starts by calculating an adaptive threshold value depending on the illumination model and converts the image by comparing each column pixels individually with the adaptive threshold value. The proposed method was evaluated on smartphone face video dataset and compared with the Global image threshold using Otsu's method. The experimental results showed the outperformance of the proposed method.

References

1. X. Tan and B. Triggs, (2011). Enhanced local texture feature sets for face recognition under difficult lighting conditions, IEEE Trans. Image Process., vol. 19, no. 6, pp. 1635–1650.
2. CR Singh and HY Patil,(2016). A shearlet transform based illumination invariant 2-D face recognition, Electrical, Electronics, and Optimization, ieeexplore.ieee.org.
3. Choi Y, Kim H-I, Ro YM,(2016). Two-step learning of deep convolutional neural network for discriminative face recognition under varying illumination, Electronic Imaging.
4. M. Ochoa-Villegas, J. Nolazco-Flores, O. Barron-Cano, I. Kakadiaris,(2015). Addressing the illumination challenge in two-dimensional face recognition: a survey, I ET Computer Vision. 9 (6) 978–992.
5. C. Hu, X. Lu, M. Ye, W. Zeng,(2017). Singular value decomposition and local near neighbors for face recognition under varying illumination, Pattern Recognition 64 ,60–83, Elsevier.
6. RD Atmaja, MA Murti, J Halomoan,(2016). An image processing method to convert RGB image into binary, Indonesian Journal of Electrical Engineering and Computer Science.
7. S Chauhan, E Sharma, A Doegar,(2016). Binarization techniques for degraded document images—A review, ieeexplore.ieee.org
8. Payel Roy, Saurab Dutta, Nilanjan Dey, Goutami Dey, Sayan Chakraborty and Ruben Ray, (2014). Adaptive thresholding: A comparative study, IEEE conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT), Kanyakumari, pp. 1182- 1186.
9. W. Niblack, (1986). An introduction to digital image processing, Strandberg Publishing Company Birkeroed, Denmark, Denmark. 87-872-0055-4.

10. J. Bernsen, (1986). Dynamic thresholding of gray level images," Proc. Intl. Conf. on Pattern Recognition, pp. 1251–1255.

11. J. Sauvola, T. Seppanen, S. Haapakoski, and M. Pietikainen,(1997). Adaptive document binarization,4th Int. Conf. on Document Analysis and Recognition, Ulm Germany, pp. 147–152.

12. Muhammad Burhan Khan, Humaira Nisar, Ng Choon Aun, Po Kim Lo, (2016). Iterative region based Otsu thresholding of bright-field microscopic images of activated sludge, IEEE EMBS Conference on Biomedical Engineering and Sciences (IECBES).

13. Hongmin Cai, Zhong Yang, Xinhua ,Weiming Xia, and Xiaoyin Xu, (2014). A New Iterative Triclass Thresholding Technique in Image Segmentation, IEEE transactions on image processing, vol. 23, no. 3.

14. P. Wellner, (1993). Adaptive Thresholding for the Digital Desk, Xerox Research Center Technical Report n. EPC-1993-110.

15. D. Bradley and G. Roth, (2007). Adaptive thresholding using the integral image, Journal of Graphics GPU, & Game Tools, 12(2):13–21.

16. K. Peuwnuan, K. Woraratpanya, K. Pasupa,(2016). Modified adaptive thresholding using integral image, in Proceeding of 13th International Joint Conference on Computer Science and Software Engineering, 13-15 , Khon Kaen, Thailand.

17. G. Fahmy, A. Elsherbeeny, S. Mandala, M. Abdel-Mottaleb, and H. Ammar, (2006). The effect of lighting direction/condition on the performance of face recognition algorithms, SPIE Conference on Biometrics for Human Identification, vol. 6202, Apr, pp. 188–200.