HUMAN FACE VERIFICATION UNDER ILLUMINATION VARIATION

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To

The Honorable Soul of My Father, whose Children's Success was His Only Wish.

To

My Kind Mother

To

My Beloved Wife and Son without their Support and Understanding It Would Have been Impossible to Achieve Such a Goal

To

The Respected Soul of My Previous Supervisor the Late Prof. Datuk.Dr. Marzuki Khalid Whom I Have Loved As a Father

And Last But Not Least, To

My Dear Brothers

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ABSTRACT

The appearance of a face will vary intensely when the illumination changes. The changes in the illumination conditions during image capturing make it difficult to obtain accurate face verification. Changes in illuminations results in two main problems, which are reflections and shadows. One of the most important aspects influencing the verification accuracy is illumination normalization. This thesis explored the use of fusion normalization methods to improve the performance of face verification under illumination variation. It has been shown that a single normalization technique is inadequate to solve the problems of illumination. In this study, several normalization methods such as Discrete Wavelet Transform, Discrete Cosine Transform, and Classified Appearance based Quotient Image were investigated for illumination normalization. A verification process was performed for each normalization technique and the outputs of the process, which were the likeness scores would be fused together to improve the final output. In the verification step, Principal Component Analysis was used to reduce the vector size of image and Linear Discriminant Analysis was used to extract discriminative information. In addition, un-trained fusion methods such as Max-Rule, Min-Rule, and Ave-Rule were used to get a unified decision with a reduced error rate. Besides that, fusion normalization methods were also used to solve all problems caused by illumination. The experiments were done on XM2VTS and Yale database B. The results of this research showed that the efficiency of Ave-Rule technique is better than other methods for XM2VTS, and the best fusion method for Yale database B is Min-Rule. To evaluate the techniques, the results have been compared with the outcomes of the fusion of each pair of the normalization methods as well as the results obtained from using other techniques. The comparison showed that the fusion of the three normalization techniques offered a better performance as compared to the fusion of two illumination normalization methods. Furthermore, the performance of face verification based on the fusion of the normalization methods was better in comparison to a single normalization technique.

ABSTRAK

Keketaraan penampilan wajah akan berbeza apabila wujudnya perubahan pencahayaan. Perubahan pencahayaan dalam merakam imej menyukarkan proses pengesahan muka dengan ketepatan yang baik. Perubahan pencahayaan akan menyebabkan dua masalah utama iaitu pantulan dan bayang-bayang. Normalisasi pengcahayaan adalah antara aspek penting yang mempengaruhi kualiti pengesahan. Tesis ini meneroka penggunaan kaedah gabungan normalisasi untuk meningkatkan kualiti pengesahan muka. Kaedah normalisasi tunggal tidak memadai dalam memperbaiki masalah ini secara amnya. Dalam kajian ini, beberapa kaedah normalisasi seperti Pengubah Wavelet Diskret, Pengubah Kosinus Diskret, dan Klasifikasi Rupa – berdasarkan Kadar Imej dianalisis dan digunakan sebagai kaedah normalisasi. Proses pengesahan dijalankan untuk setiap kaedah normalisasi dan proses outputnya adalah skor bandingan yang digabung bersama untuk memperbaiki keseluruhan output. Dalam langkah pengesahan, digunak Analisis Komponen Utama an untuk mengurangkan dimensi vektor maklumat imej, dan Analisis Diskriminasi Linear digunakan untuk mengoptimumkan maklumat diskriminatif. Di samping itu, kaedah gabungan tidak-terlatih seperti Peraturan-Maksima, Peraturan-Minima, dan Peraturan-Purata digunakan untuk mendapatkan keputusan bersatu dengan ralat dikurangkan. Selain itu, kaedah gabungan normalisasi juga digunakan untuk menyelesaikan masalah pengcahayaan. Eksperimen telah dijalankan pada XM2VTS dan Pangkalan Data Yale B. Keputusan menunjukkan kaedah Peraturan-Purata adalah terbaik berbanding kaedah lain untuk XM2VTS, dan gabungan Peraturan-Minima adalah terbaik untuk Pangkalan Data Yale B. Keputusan daripada kaedah yang dicadangkan akan dibandingkan dengan setiap kaedah gabungan normalisasi dan beberapa kaedah lain. Kualiti pengesahan dengan gabungan tiga kaedah normalisasi adalah lebih baik berbanding gabungan dua kaedah normalisasi. Di samping itu, pengesahan muka dengan kaedah gabungan normalisasi juga adalah lebih baik berbanding kaedah normalisasi tunggal.

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LIST OF ABBREVIATIONS

HE	-	Histogram Equalization
LBP	-	Local Binary Patterns
WT	-	Wavelet Transforms
SH	-	Spherical Harmonics
QI	-	Quotient Image
DCT	-	Discrete Cosine Transform
HF	-	Homomorphic Filtering
CAQI	-	Classified Appearance-based Quotient Image
FLD	-	Fisher Linear Discriminant
MAP	-	Maximum A Posterior
QIR	-	Quotient Illumination Relighting
GIIS	-	Generic Intrinsic Illumination Subspace
MQI	-	Morphological Quotient Image
PCA	-	Principal Component Analysis
AHE	-	Adaptive Histogram Equalization
BHE	-	Block-based Histogram Equalization
LTP	-	Local Ternary Patterns
LDCT	-	Local Discrete Cosine Transform
DWT	-	Discrete Wavelet Transform
IRM	-	Illumination Reflectance Model
RLI	-	Rule of Lighting Invariance
IVIW	-	Improved Variable Illumination on Wavelet
HMV	-	Homomorphic Vertical filtering
HMH	-	Homomorphic Horizontal filtering
SQI	-	Self-Qutient Image
LDA	-	Linear Discriminant Analysis
EGFC	-	Ensemble based Gabor Fisher Classifier

ANN	-	Artificial Neural Networks
HMM	-	Hidden Markov Models
LEM	-	Line Edge Map
SVM	-	Support Vector Machine
MCS	-	Multiple Classifier Systems
MRF	-	Markov Random Field
FAR	-	False Acceptance Rate
FRR	-	False Rejection Rate
EER	-	Equal Error Rate
HTER	-	Half Total Error Rate
GT	-	Global Threshold

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CHAPTER 1

INTRODUCTION

In this chapter, an introduction to the current study is presented. First, the background of the problem to be solved is explained. After that, the statement of problem, objectives, and scope of study are respectively illustrated.

1.1 Background of the Problem

Face recognition procedure is one of the most prosperous applications of image processing in which people execute adeptly and routinely in their daily lives. Face recognition and face verification are two categories of a face identification system that have acquired noticeable attention from forty years ago. Because of their wide usages in law enforcement, commerce, security, multimedia management and other areas, they have consequentially attracted various areas of research, such as pattern recognition, biometrics, computer vision, machine learning, and computer graphics. In addition, wide accessibility of powerful and low-cost desktop and embedded computing systems have produced a huge interest in automatic images processing in a number of these applications.

A face-identification system automatically identifies faces present in images or videos. Face identification and face verification are two modes of this system. Face identification (or recognition) is a one-to-many comparing processes, which compares a claimed face image , called probe image, against all the template images in a database to specify the identity of the query face. "Face verification is used in order to determine whether an identity claim is false or true. Actually, face verification is a one-to-one matching procedure which compares a probe image with a stored template face image whose identity is being claimed".

In many of the face verifications applications (Chellappa et al., 1995), the performance and accuracy in controlled environments have now reached a satisfactory level; however, there are still many challenges presented by uncontrolled environments. Some of these challenges are demonstrated by the problems caused by variations in face pose, illumination, and expression. In particular, the effect of variation in the illumination conditions which results in dramatic changes in the face appearance, is one of those challenging problems that a practical face verification faces (Zhao et al., 2003)

Several major problems that are still being addressed by researchers are explained below:

1. **Facial deformation:** Changing the mood, stress, and expressions makes human faces non-rigid and endures deformations. The underlying muscle and tissue structure guides these deformations. They are not arbitrary and it is very difficult to model or analyze these fluctuations from normal images.

2. **Aging:** Appearance of human faces varies due to aging. Faces of various persons age differently depending on habits, stress, health, race, and climate that make the process of verification under aging very difficult.

3. **Cosmetic changes:** In additional natural variations, makeup, surgery, growing or shaving facial hair can deliberately change the face appearance. Sometimes human face verification or recognition across this problem is difficult.

4. **Occlusion:** When another object occludes a part of human face, occlusion will happen.

5. **Pose variation:** In this problem, the similar face seems variously when the viewing condition is changed. Human face recognition and verification under changing pose is very difficult.

6. **Illumination variation:** In this problem, alike face appears variously due to vary lighting condition. More specifically, the variations by illumination could be bigger than the variation among persons. The consequences of prior researches show that important illumination changes cause dramatic variations in the production coefficient vectors, and hence can seriously decrease the performance of face identification.

Recently, many researchers have focused on robust face recognition and verification under pose, expression and illumination variations. The appearance of a face will extremely change when the lighting condition varies. In unnatural illumination conditions of image capturing, the face verification process is very hard. Illumination problem appears where the similar face occurs variously caused by illumination variation. Changes in lighting conditions make face authentication an even more challenging and hard process. Moreover, variation in appearance due to change in the lighting conditions significantly influence the face identification performance. "In order to illustrate a variation of facial appearances produced by illumination, the appearances are sorted into two principal categories: reflections, shadows. Diffuse reflection and specular reflection are two parts of reflection, which have quite different characters and also cast shadow and attached shadow, are two subparts of shadow category" (Nishiyama and Yamaguchi, 2006).

Image capture, face detection and location, face alignment and normalization, feature extraction, face matching and score generation, and decision are six modules of a complete face verification system (Short, 2006).

1. **Image capture:** A claimed image is captured with a digital camera. This image is called probe image. The substance of the probe image

is decided by the position of the person relative to the camera, the expression, poses of the claimant and the changing lighting conditions of the image capture.

2. **Face detection and Location:** A probe image contains the face of a person and a potentially cluttered background scene. In the detection step, the position of the face in the image is detected.

3. **Face alignment and normalization:** In this step, the position and size of each detected face are appraised. A normalization procedure includes Geometric and Photometric parts. Since the size of facial image within the input image varies with the distance between person and camera, geometrical normalization is needed. Thus, the face should be cropped from the image and geometrically changed to a pre-determined fixed size. The photometric compensation is used to eliminate unwanted lighting effects from the probe image. In some cases, the photometrical normalization process can be done before, or before and after the geometric normalization procedure, also it can occur in the past, or before and after the detection process.

4. **Feature extraction:** The efficient information, which is applicable for identifying faces of different persons, is supplied in this step.

5. **Face matching and score generation:** The feature vectors of compensated image are then compared with one or more claimed images, which are in a gallery. This comparison process generates a score, showing how well the probe image matches the gallery.

6. **Decision:** In order to determine the probe is accepted or rejected, the score is compared with a threshold.

1.2 Statement of the Problem

Several different studies on face verification under illumination variation tried to define proper platforms for compensation of influence for varying lighting on face verification and recognition. It has been shown experimentally and theoretically that differences in appearance caused by illumination are bigger than differences between individuals. Various approaches have been suggested to overcome illumination problem but in the majority of them, only controlled condition was considered. However, it is important to consider uncontrolled conditions to emulate the actual applications of face verifications or identification such as security.

Various facial images of the same people may be changed due to alterations in photometric and geometric parameters. Geometric characteristics denote the geometry of the camera with respect to the face being captured containing distance and orientation and pose. Photometric parameters notify the illumination conditions such as number, size, intensity, placement, and color of light sources. It is clear that varying lighting conditions can create too dark or too light images, which can produce some problems in recognition or verification process or reduce the performance of them.

Researchers have suggested several techniques to create illumination invariant face images. These methods can be divided into 3 categories. In the first category, which is named preprocessing approach, the illumination is compensated by applying pre-processing methods on the pixel values utilizing information from the local area around that pixel. "Local Binary Patterns" (Heusch et al., 2006), "Histogram Equalization"(Shan et al., 2003) , and "Wavelet Transform" (Du and Ward, 2005) are three samples of this method. The simplicity and being in a direct manner are two properties of these methods. These approaches are unable to model the global illumination conditions. In invariant feature extraction methods, investigators try to extract facial features, which are changeless to illumination. Edge map and Gabor–like filters are two examples of this approach". (Adini et al., 1997). Third category is named physical face modeling. In this category, investigators appraise a global physical model of the illumination mechanism and its interaction with the facial surface . "Quotient Image"(Shashua and Riklin-Raviv, 2001), "Spherical Harmonics" (Basri and Jacobs, 2003), "3D morphable" (Blanz and Vetter, 1999), and "Discrete Cosine Transform" (Chen et al., 2006) are examples of this category.

Nowadays, because of the effect of changing in the illumination conditions, which makes strong variations in the appearance of a face, illumination invariant face verification is described by various approaches (Zhao et al., 2003). To be more particular, the altering energy and direction distribution of the ambient illumination, together with the 3D structure of the human face, can cause major variations in the shading and shadows on the face. Such changes in the face appearance due to variation illumination can be much larger than the change due to personal identity.

Most of the existing approaches attempt to normalize diffuse reflection in illumination variation. There are still many challenges in specular reflection, attached shadow and cast shadow. Diffuse reflection happens when the object scatters the incident. When the object clearly reflects incident light, specular reflection will appear. In the attached shadow, the object blocks the incident light. When the incident light is hindered by a different object, cast shadow appears (Nishiyama et al., 2008). Figure 1.1 shows various classification of facial appearance caused by illumination (Nishiyama et al., 2008).

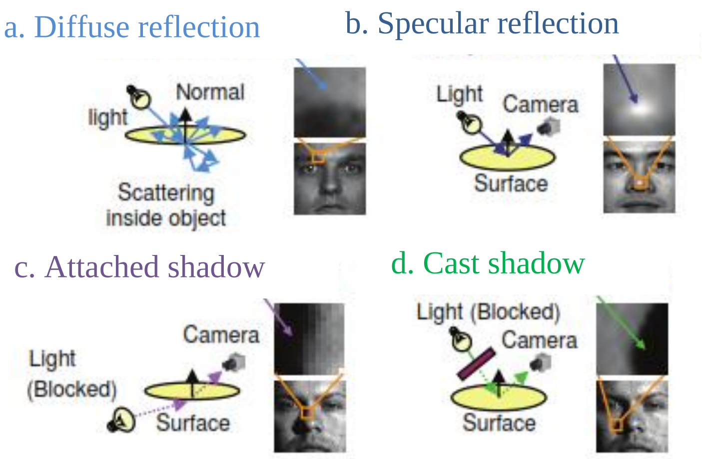

Figure 1.1 Classifying of facial appearance (Nishiyama et al., 2008). (a) "Diffuse reflection"; (b) "Specular reflection"; (c) "Attached shadow"; (d) "Cast shadow"

This research aims to provide a fusion approach to combine three illumination normalization methods together for increasing accuracy and performance of human face verification under illumination variations, including "diffuse reflections", "specular reflections", "attached shadow" and "cast shadows". Because of using three effective illumination normalization techniques and compensating all four mentioned problems produced by illumination, fusion of these methods is very impressive to improve accuracy and performance of face verification under illumination variation. The method of fusion is compared against existing methods of using single normalization techniques for face verifications under varying illuminations.

1.3 Objectives of the Study

1. To investigate state of the art in Illumination normalization approaches.

2. To develop a fusion illumination normalization method for face verification under illumination variations.

3. To evaluate the proposed technique with other current methods with respect to the related performance criteria.

1.4 Scope of the Study

In this study, only lighting variation is considered and other problems in human face verification are not regarded. The face images considered are in frontal position.

For implementation of face verification under illumination variations, three processes were considered as important, which are: preprocessing normalization, physical face modeling, and photometric Normalization.

In this research, several preprocessing normalization methods such as Histogram Equalization (HE) (Shan et al., 2003) , Local Binary Patterns (LBP) (Adini et al., 1997; Heusch et al., 2006), and Discrete Wavelet Transforms (DWT) (Goh et al., 2009) were surveyed, and Spherical Harmonics (SH) (Adini et al., 1997),and Discrete Cosine Transform (DCT) (Chen et al., 2006), Quotient Image (QI) (Shashua and Riklin-Raviv, 2001), and "3D morphable" (Blanz and Vetter, 1999) as physical face modeling methods were studied, and Homomorphic Filtering (HF) (Delac et al., 2006) ,and "Classified Appearance-based Quotient Image" (CAQI) (Nishiyama and Yamaguchi, 2006) as photometric normalization approaches were investigated. Finally, DCT, DWT, and CAQI were used to normalization process.

Un-trained fusion methods such as Max-Rule, Min-Rule, and Ave-Rule were used in order to get a unified decision with a reduced error rate.

The experiments were done on XM2VTS and Yale database B.

1.5 Summary

Over the last three decades, biometrics has been applied as an automated technique to identify individuals according to their behavioral or physical parameters. A biometric system is a pattern identification system. Various biometric properties such as DNA, sample of voice, and face are used in different systems. Face recognition and verification are categorized as natural uncomplicated biometric techniques. In face verification, the investigators determine whether an identity claim is true or false. In face recognition, in order to specify the identity of the query face, researchers compare a probe image against all template images in a database.

In spite of numerous usages of face identification and the availability of feasible approaches after thirty-five years of research, several challenges such as occlusion, varying to pose, illumination variation, expression remain unsolved that researchers should address. One of the critical factors, which effects on face identification and its performance is illumination variation. In this problem, similar face appears variously due to vary lighting condition.

Nowadays, several approaches exist to overcome the illumination problem. Most of the existing approaches attempt to normalize "diffuse reflection" in illumination variation. There are still many challenges in "specular reflection", "attached shadow" and "cast shadow". This research attempts to supply fusion approach to combine three illumination normalization methods together for increasing performance in normalization of illumination variation.

As mentioned in scope of the study, DWT and DCT and CAQI techniques were chosen to combine in order to cope with illumination variation in face verification. Moreover, XM2VTS and Yale database B were used for the experiment.

In this study, in order to obtain better performance in face verification under illumination variation, un-trained fusion techniques that are Min-Rule, Max-rule, and Ave-rule were applied.

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