UNIVERSITI PUTRA MALAYSIA

INTEGRATED FACE DETECTION APPROACH FOR FAR IMAGE APPLICATION

TANKO DANIEL SALKA

INTEGRATED FACE DETECTION APPROACH FOR FAR IMAGE APPLICATION

By

TANKO DANIEL SALKA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

October 2016

DEDICATIONS

This thesis is dedicated to my parent Mr. & Mrs. Tanko Duste Salka

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

INTEGRATED FACE DETECTION APPROACH FOR FAR IMAGE APPLICATION

By

TANKO DANIEL SALKA

October 2016

Chairman : **Marsyita Binti Hanafi, PhD**
Institute : **Engineering**

Face detection has been widely explored over the past few decades. Despite the significant progress in detecting human faces in unconstrained and complex images, face detection remains a challenging problem in computer vision, especially for the images captured at a far distance making it difficult to detect face region. Other factors affecting face detection are illumination conditions, pose and ethnicity. Therefore, the need of a robust and efficient face detection algorithm is required to tackle these problems. This thesis presents an Integrated face detection approach for far image application, which solves the problems mentioned. The proposed approach consists of an Illumination compensation method, a Skin segmentation method, a Noise reduction method and Euler method. In the proposed illumination compensation method, the R, G and B components were normalized using Gray World Theory (GWT), a theory that compensates the illumination effect. The skin segmentation method consists of a combination of RGB filter, the newly proposed filter known as a Dynamic chrominance filter and an edge detector. The function of the RGB filter is to reject pixels with the RGB colors that are most probably non-skin, so that the computation in the following stages does not apply to all pixels. In this method, the final decision of a pixel belongs to the class "skin is made by the Dynamic chrominance filter and the edge detector. The noise reduction method in the proposed algorithm consists of a combination of a morphological filter and a rejection method. The last stage of the algorithm is to apply the Euler method, in which its function is to search for the facial features. The features indicate whether the detected skin region is a region that represents face or non-face. Also, an experiment was conducted on the developed database known as Large Variability Surveillance Camera Face (LVSC) database and FEI database, the proposed method produced a detection rate of 98.4% and 100%, respectively.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENDEKATAN BERSEPADU PENGESANAN WAJAH BAGI APLIKASI KAMERA LITAR TERTUTUP (CCTV)

Oleh

TANKO DANIEL SALKA

Oktober 2016

Pengerusi : **Marsyita Binti Hanafi, PhD**
Institut : **Kejuruteraan**

Penerokaan bidang pengesanan wajah bagi imej digital telah giat dijalankan sejak beberapa dekad yag lalu. Di sebalik perkembangan yang ketara ini, pengesanan wajah dalam imej yang tidak dikawal dan kompleks kekal menjadi satu masalah dalam bidang penglihatan komputer terutamanya untuk imej yang diambil dari jarak yang jauh yang mana membuatkan proses pengesanan rantau wajah menjadi sangat sukar. Faktor lain yang turut mempengaruhi proses pengesanan ini ialah keadaan pencahayaan, variasi gaya dan kepelbagaian etnik. Oleh itu, keperluan algoritma pengesanan wajah yang mantap dan cekap diperlukan untuk menangani masalah-masalah ini. Tesis ini membentangkan satu kaedah pengesanan wajah bersepadu bagi aplikasi imej jarak jauh, bagi mengatasi masalah yang telah disebutkan sebelum ini. Pendekatan yang dicadangkan terdiri daripada kaedah pampasan pencahayaan, teknik pensegmenan kulit, kaedah pengurangan hingar dan teknik Euler. Dalam kaedah pampasan pencahayaan, komponen R, G dan B ternormal menggunakan teknik Teori Dunia Kelabu, satu teori bagi mengimbangi kesan pencahayaan. Kaedah pensegmenan kulit pula terdiri daripada gabungan penapis RGB yang baru yang dicadangkan di dalam tesis ini, penapis krominan dinamik dan pengesan tepi. Fungsi penapis RGB ialah bagi menyingkirkan piksel dengan nilai RGB yang berkemungkinan besar bukan kulit, supaya proses pengiraan di peringkat seterusnya tidak dilaksanakan pada kesemua piksel. Di dalam kaedah ini, keputusan muktamad sama ada sesuatu piksel itu tergolong dalam kelas kulit atau tidak, adalah ditentukan oleh penapis krominan dinamik dan pengesan tepi. Teknik pengurangan hingar dalam algoritma yang dicadangkan ini terdiri daripada gabungan penapis morfologi dan kaedah penyingkiran. Fasa terakhir dalam algoritma ini ialah untuk mengaplikasi kaedah Euler, yang mana ia berfungsi untuk mendapatkan ciri-ciri wajah, seperti mata, hidung dan mulut. Ciri-ciri tersebut menentukan sama ada rantau kulit yang dikesan itu

mewakili muka atau tidak. Satu eksperimen telah dijalankan ke atas pangkalan data yang telah dibangunkan yang dikenali sebagai Wajah Kamera Pengawasan Kebolehubahan Besar Large Variability Surveillance Camera Face (LVSC) dan pangakalan data FEI, dan kaedah yang dicadangkan masing-masing mencapai kadar pengesanan sebanyak 98.4% dan 100%.

ACKNOWLEDGEMENTS

First of all, I would like to express my gratitude to God almighty, for his wisdom, understanding and knowledge he granted me during the course of life and moment of truth.

I would like to express my deepest and warmest gratitude to my wonderful supervisor, Dr. Marsyita Binti Hanafi, for her support, guidance, friendly supervision and constant encouragement which made me to have focus and direction in my research. I fell privileged to have her as my supervisor. My sincere appreciation also goes to members of my supervisory committee Associate Professor Dr. Sharifah Mumtazah Syed Ahamad Abdul Rahman and Dr. Syamsiah Binti Mashohor, for their support, valuable suggestions and encouragement.

The author would like to thank his lovely parent (Mr. and Mrs. Tanko Duste Salka) and his siblings (Joy, Janet and David) the best gift anyone could have asked, for their unconditional love, prayers, encouragement and support that made me strong to complete my research work. May God bless you all and I really love you all. A big thank you to Mr. and Mrs. Isah Agaie Aliyu for their assistance and motivation, I would not have been able to do this research without you.

I am thankful for all the members of computer and embedded systems engineering laboratory from assistant engineers Mr. Hakim, Mr. Hisham, Mr. Sallehuddin and Mrs. Azlina to my fellow Lab mates most especially Mr. Mohd Hafrizal Bin Azmi and his family who all accepted me warmly and kindly from the beginning of my stay at the department. Finally, thanks to my awesome friends in Nigeria Zarephath Andrew, Habila Joshua and Iliyasu Matthew who contributed through their prayers and encouragement, may God Almighty bless you all.

I certify that a Thesis Examination Committee has met on 18 October 2016 to conduct the final examination of Tanko Daniel Salka on his thesis entitled "Integrated Face Detection Approach for Far Image Application" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Syed Abd Rahman Al-Haddad bin Syed Mohamed, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Abd. Rahman bin Ramli, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Hezerul Abdul Karim, PhD
Associate Professor
Multimedia University
Malaysia
(External Examiner)

NOR AINI AB. SHUKOR, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 22 November 2016

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science.
The members of the Supervisory Committee were as follows:

Marsyita Binti Hanafi, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairperson)

Syamsiah Binti Mashohor, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Sharifah Mumtazah Syed Ahamad Abdul Rahman, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature:_____ Date:_____

Name and Matric No: Tanko Daniel Salka, GS39960

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: _____
Name of
Chairman of
Supervisory
Committee :Marsyita Binti Hanafi, PhD

Signature: _____
Name of
Member of
Supervisory
Committee: Syamsiah Binti Mashohor, PhD

Signature: _____
Name of
Member of
Supervisory
Committee:Sharifah Mumtazah Syed Ahamad Abdul Rahman, PhD

TABLE OF CONTENTS

	Page
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iv
APPROVAL	v
DECLARATION	vii
LIST OF TABLES	xi
LIST OF FIGURES	xiii
LIST OF ABBREVIATIONS	xvi
CHAPTER	
1 INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	1
1.3 Aim of the Research	2
1.4 Objectives of the Research	2
1.5 Scope of Work	2
1.6 Research Contributions	3
1.7 Thesis Outline	3
2 LITERATURE REVIEW	4
2.1 Introduction	4
2.2 Knowledge-Based Method	4
2.3 Feature-Based Method	6
2.4 Template matching method	8
2.5 Appearance-based Methods	9
2.6 Hybrid Based Method	11
2.7 Existing Database	13
2.7.1 FERET Database	13
2.7.2 Yale Face Database B	14
2.7.3 MUCT Database	14
2.7.4 AR Face Database	15
2.7.5 Surveillance Camera Face Database	15
2.7.6 An Annotated Crowd Video Face (ACVF-2014) Database	16
2.7.7 IARPA Janus Benchmark A (IJB-A) Database	16
2.8 Summary	17
3 METHODOLOGY	19
3.1 Introduction	19

3.2 Description of the Proposed Database 20
3.2.1 Experimental set-up 20
3.2.2 Image Acquisition Procedures 21
3.3 Illumination Compensation 25
3.4 Skin Segmentation Method 25
3.4.1 RGB Filter 25
3.4.2 Dynamic Chrominance Filter 30
3.4.3 Edge Detection 33
3.5 Noise Rejection Method 34
3.5.1 Morphological Filter 34
3.5.2 Small Blob Filter 35
3.6 Euler Method 36
3.7 Conclusion 38

4 RESULT AND DISCUSSION 40
4.1 Introduction 40
4.2 Illumination Compensation 40
4.3 Skin Segmentation Method 42
4.3.1 RGB Filter 42
4.3.2 Dynamic Chrominance Filter 43
4.3.3 Edge Detection 54
4.4 Euler Method 56
4.5 Comparison of Face detection methods 60

5 CONCLUSION AND FUTURE WORK 61
5.1 Conclusion 61
5.2 Future Works 62

REFERENCES 63
APPENDICES 69
BIODATA OF STUDENT 79
LIST OF PUBLICATIONS 80

LIST OF TABLES

Table		Page
2.1	Result of face detection approach for single face images and multi-face images	6
2.2	Accuracy of the system for single and multiple person	8
2.3	Results obtained from Wu et al.	11
2.4	Details of the existing databases	18
3.1	Indoor and Outdoor PTZ Camera Specifications	20
3.2	Details of the images and videos captured	21
3.3	Threshold values for the $\boldsymbol{H_1}, \boldsymbol{H_2}, \boldsymbol{S}$ and $\boldsymbol{I}$ components	31
3.4	The chrominance components in each color space.	31
4.1	The performance evaluation of using 400 images from the training dataset.	40
4.2	Threshold values for the $\boldsymbol{a^*}$, $\boldsymbol{b^*}$, $\boldsymbol{U}, \boldsymbol{V}$, $\boldsymbol{H}, \boldsymbol{S}$, $\boldsymbol{I}, \boldsymbol{Q}$, $\boldsymbol{H_{new}}, \boldsymbol{S_{new}}$, $\boldsymbol{r}, \boldsymbol{g}$ and $\boldsymbol{b}$ components	47
4.3	Performance of the color components	48
4.4	Accuracy of the color components performance	48
4.5	The new threshold values for the $\boldsymbol{a^*}$, $\boldsymbol{b^*}$, $\boldsymbol{H}, \boldsymbol{S}, \boldsymbol{I}$ and $\boldsymbol{Q}$ components in the first set (shifted at 5%).	49
4.6	Threshold values for the $\boldsymbol{a^*}$, $\boldsymbol{b^*}$, $\boldsymbol{H}, \boldsymbol{S}, \boldsymbol{I}$ and $\boldsymbol{Q}$ components in the second set (shifted at 10%).	50
4.7	Threshold values for the $\boldsymbol{a^*}$, $\boldsymbol{b^*}$, $\boldsymbol{H}, \boldsymbol{S}, \boldsymbol{I}$ and $\boldsymbol{Q}$ components in the third set (shifted at 15%).	50
4.8	Confusion matrix for the combinations of $\boldsymbol{a^*}$, $\boldsymbol{b^*}$, $\boldsymbol{H}, \boldsymbol{S}, \boldsymbol{I}$ and $\boldsymbol{Q}$ components original value.	50
4.9	Accuracy for the combinations of $\boldsymbol{a^*}$, $\boldsymbol{b^*}$, $\boldsymbol{H}, \boldsymbol{S}, \boldsymbol{I}$ and $\boldsymbol{Q}$ components original value.	51

4.10 Confusion Matrix for the combinations of a^*, b^*, H, S, I and Q components at 5%. 51

4.11 Accuracy for the combinations of a^*, b^*, H, S, I and Q components at 5%. 51

4.12 Confusion Matrix for the combinations of a^*, b^*, H, S, I and Q components at 10%. 52

4.13 Accuracy for the combinations of a^*, b^*, H, S, I and Q components at 10%. 52

4.14 Confusion Matrix for the combinations of a^*, b^*, H, S, I and Q components at 15% 52

4.15 Accuracy for the combinations of a^*, b^*, H, S, I and Q components at 15%. 53

4.16 Detection rate based on ethnicity performance 53

4.17 Overall performance of skin segmentation method 56

4.18 Face detection experimental results 57

4.19 Comparison with several methods 60

LIST OF FIGURES

Figure		Page
2.1	Parameters for knowledge representation of a face image	5
2.2	FERET Database	13
2.3	Yale face database B	14
2.4	MUCT Database	14
2.5	Example of images from AR Face Database	15
2.6	Example of images from Surveillance Camera face database (SCface)	15
2.7	Example of images from An Annotated Crowd Video Face Database	16
2.8	Example of images from IARPA Janus Benchmark A (IJB-A) Database	16
3.1	The proposed face detection	19
3.2	Equipment used to develop the database	20
3.3	The proposed face detection	21
3.4	Example of images that were captured at three different sessions and for each session, the participants wore different clothes.	22
3.5	Some example of images that were captured from a single subject with different scales, poses, facial expressions, illuminations occlusions and night mode images.	23
3.6	Example of images that were captured across different ethnics	24
3.7	Example of the skin masks used in the training across various ethnic groups.	26
3.8	Histograms developed using African's skin mask. (a) *R* channel, (b) *G* channel and (c) *B* channel	27
3.9	Histograms developed using Malay's skin mask. (a) *R* channel,(b) *G* channel and (c) *B* channel	27
3.10	Histograms developed using Chinese's skin mask. (a) *R* channel, (b) *G* channel and (c) *B* channel	28

3.11 Histograms developed using Other's skin mask. (a) *R* channel, (b) *G* channel and (c) *B* channel 28

3.12 The process in the Dynamic chrominance filter. 30

3.13 Illustration of the opening process (a) Original image, (b) Structural element; x = origin, (c) Image after opening 35

3.14 Illustration of the closing process (a) Original image, (b) Structural element; x = origin, (c) Image after closing 35

3.15 Example of images with holes 37

3.16 Illustration of h and h_1 37

3.17 Example of segmented images 38

3.18 Example of segmented images 38

4.1 (a) Original images. Results obtained using (b) GWT, (c) HF (d) CLAHE 41

4.2 The example of the detected skin region. 42

4.3 The example of the skin and non-skin regions detected by RGB filter. 43

4.4 Histogram of the H and S components for Malays 43

4.5 Histogram of the H and S components for Africans 44

4.6 Histogram of the H and S components for Chinese 44

4.7 Histogram of the H and S components for Other 44

4.8 Histogram of the a* and b* components for Malays 45

4.9 Histogram of the a* and b* components for Africans 45

4.10 Histogram of the a* and b* components for Chinese 45

4.11 Histogram of the a* and b* components for Other 46

4.12 Histogram of the I and Q components for Malays 46

4.13 Histogram of the I and Q components for Africans 46

4.14 Histogram of the I and Q components for Chinese 47

4.15 Histogram of the I and Q components for Other 47

4.16 Illustration of the shifting of $\boldsymbol{X}_{min}$ and $\boldsymbol{X}_{max}$ from the generated histogram 49

4.17 Results of Dynamic chrominance filter. 54
4.18 Example of the edges detected by the Canny edge detector 55
4.19 Example of the inverted edges 55
4.20 Example of the skin region produced by skin segmentation method. 55
4.21 Example of results that passed Euler Test 56
4.22 Example of the detected faces 56
4.23 Example of the detected faces with the updated face region 57
4.24 Example of faces detected at different illuminations. 58
4.25 Example of faces detected at different poses. 58
4.26 Example of faces detected at different scales. 58
4.27 Example of faces detected with occlusions. 59
4.28 Example of false detection. 59
4.29 FEI Database 59

LIST OF ABBREVIATIONS

CCTV	Close Circuit Televison
HCI	Human Computer Interaction
PCA	Principal Component Analysis
NN	Neural Network
SVM	Support Vector Machine
GWT	Gray World Theory
HF	Homomorphic Filtering
CLAHE	Contrast Limited Adaptive Histogram Equalization
E	Euler Number
CC	Connected Component
H	Hole
bb	Bounding box
PTZ	Pan - Tilt - Zoom Camera
SCface	Surveillance Camera Face Database
PSNR	Peak Signal to Noise Ratio
TP	True Positive
TN	True Negative
FP	False Positive
FN	False Negative
TDR	True Detection Rate
FDR	False Detection Rate
LVSCF	Large Variability Surveillance Camera Face Database
MUCT	Milborrow University of Cape Town
FERET	Facial Evaluation Recognition Technology

CHAPTER 1

INTRODUCTION

1.1 Background

A face detection system is a computer application that detect the presence of human faces in a given image or video frame and return the location of the faces. Over the past few years, face detection has received great attention from the scholars due to its requirement in many applications such as automatic face recognition, human-computer interaction (HCI), video surveillance, and content-based image retrieval.

Early face detection systems can be tracked as far back in 1970s, where heuristic and anthropometric techniques were used [1, 2]. These techniques were able to detect faces based on various assumptions, such as faces only appear in frontal view. The major hitch of these methods is that, any changes in image condition would result in fine-tuning of the whole system or even completely redesigning the system. However, the study of human face detection in the last decades was inspired by the appearance of human faces, which is considered as a dynamic object that comes in different color and sizes and the need in some applications such as face verification [3, 4], face recognition [5–7], facial expression recognition [8–11], emotion recognition [12, 13] and gender or age recognition [14, 15].

In recent years, detecting human faces from images captured by a CCTV camera has received great attention from the scholars. Many techniques have been developed due to the requirement of tackling the problems of detecting faces from low quality of images, which are mostly low in resolution, variation in illuminations and occlusions. In this thesis, an integrated face detection algorithm was presented that consists of a combination of several methods, namely an illumination compensation method, a skin segmentation method, a noise reduction method and Euler method. The algorithm is proposed to tackle the problem of detecting faces on images that were captured by the surveillance cameras, under various illuminations, scales and occlusions. In addition, we would like to tackle the problem of detecting faces of various ethnics.

1.2 Problem Statement

Most of the researches on face detection focus on high quality still face images and achieve good results. However, detecting human faces on images captured by surveillance cameras is a difficult task. Samir et al. [16] presented a face detection method that was based on the skin segmentation and facial geometric properties, which they achieved a good result. However, the major problem with their method was that the authors did not consider faces at different scale (distance away from the camera). Thus, more research is required to address this issue.

Another challenge comes from detecting human faces across different ethnic group

[17, 18]. Skin color differs between human races and can also be different from a person to another even with people of the same ethnicity, thus making it difficult to detect faces. In addition, illumination conditions have a very strong effect on the appearance of an object [19]. This condition may occur during image acquisition due to different lighting exposure. Face pose at different angles and expression also contribute to the increment of false detection rate [20]. The proposed techniques in this thesis follow several strategies to address the above-mentioned problems.

The availability of face database that best demonstrates a practical scenario of face samples is very important. One of the main reasons is because face detection continues to be one of the most interesting research areas in computer vision. However, there are some limitations associated with the existing database such as lack of various in scales (i.e. various distance between the subject and the camera) and the size of the datasets is quite small. Therefore, the need for a large scale, wide variability and more challenging database is required.

1.3 Aim of the Research

The aim of this work is to develop a face detection system that able to tackle the problem of detecting faces on images that are captured by CCTV system under various imaging conditions and across different ethnics.

1.4 Objectives of the Research

The objectives of this thesis are as follows.

1. To develop a database that consist of images under various conditions, such as captured at different distances, illumination across different ethnics.
2. To identify the best optimal chrominance combination that best represent skin pixels for images captured by surveillance cameras and to also identify the best illumination compensation method.
3. To propose a face detection method with an accuracy of more than 95%.

1.5 Scope of Work

In this thesis, the first task is to develop a large scale, wide variability and challenging database that consists of CCTV images and videos in both controlled and uncontrolled conditions. Then, the next task is to perform skin segmentation using two types of filters, namely, RGB and Dynamic Chrominance filters. However, the final decision of a pixel classifies as class "skin" is made by the edge detector. The noise reduction method in the proposed algorithm consists of a combination of a morphological filter and a rejection method. The last stage in the algorithm is to apply the Euler method.

1.6 Research Contributions

1. Introducing a face database, known as Large Variability Surveillance Camera Face Database (LVSCF) that consists of color images, night mode images and videos. The images were captured under various imaging conditions such as variation in illuminations, scales, poses and occlusions.
2. Introducing an optimal chrominance combination that best represent human skin pixels for images captured by surveillance cameras under various imaging condition and across different ethnic groups.
3. Improved on the existing skin detection method by introducing RGB and Dynamic Chrominance filters.

1.7 Thesis Outline

This thesis is structured as follows. Chapter one consists of sub-sections that give a broad insight into the study. These include the background, research problem statement and the contribution of the thesis. Research objectives and scope are also included this chapter. In Chapter Two, a a literature review is presented. The overviews of existing works on the face detection, including the advantages and disadvantages were discussed. The methods used in the proposed algorithm were discussed in Chapter Three. Chapter Four presents the experiment results and finally, Chapter Five presents the conclusions and future works.

BIBLIOGRAPHY

[1] T. Sakai, M. Nagao, T. Kanade, and K. Daigaku, *Computer analysis and classification of photographs of human faces*. In Proceeding of the First USA–JAPAN Computer Conference, 1972.

[2] T. Kanade, *Computer recognition of human faces*. Birkhäuser, 1977, vol. 47.

[3] Y. Taigman, M. Yang, M. Ranzato, and L. Wolf, "Deepface: Closing the gap to human-level performance in face verification," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, 2014, pp. 1701–1708.

[4] H. J. Seo and P. Milanfar, "Face verification using the lark representation," *IEEE Transactions on Information Forensics and Security*, vol. 6, no. 4, pp. 1275–1286, 2011.

[5] A. K. Jain, B. Klare, and U. Park, "Face recognition: Some challenges in forensics," in *Automatic Face & Gesture Recognition and Workshops (FG 2011), 2011 IEEE International Conference on*. IEEE, 2011, pp. 726–733.

[6] G. P. Teja and S. Ravi, "Face recognition using subspaces techniques," in *IEEE Recent Trends In Information Technology (ICRTIT), 2012 International Conference on*, 2012, pp. 103–107.

[7] G. M. Zafaruddin and H. S. Fadewar, "Face recognition: A holistic approach review," in *Contemporary Computing and Informatics (IC3I), 2014 International Conference on*. IEEE, 2014, pp. 175–178.

[8] D. H. Kim, S. U. Jung, K. H. An, H. S. Lee, and M. J. Chung, "Development of a facial expression imitation system," in *Intelligent Robots and Systems, 2006 IEEE/RSJ International Conference on*. IEEE, 2006, pp. 3107–3112.

[9] S. Chin and K.-Y. Kim, "Emotional intensity-based facial expression cloning for low polygonal applications," *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on*, vol. 39, no. 3, pp. 315–330, 2009.

[10] H. Zhang and O. Yoshie, "A fusion approach for facial expression using local binary pattern and a pseudo 3d face model," in *Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD), 2013 14th ACIS International Conference on*. IEEE, 2013, pp. 121–126.

[11] S. Eleftheriadis, O. Rudovic, and M. Pantic, "Discriminative shared gaussian processes for multiview and view-invariant facial expression recognition," *Image Processing, IEEE Transactions on*, vol. 24, no. 1, pp. 189–204, 2015.

[12] Y. Liu, O. Sourina, and M. K. Nguyen, "Real-time eeg-based human emotion recognition and visualization," in *Cyberworlds (CW), 2010 International Conference on*. IEEE, 2010, pp. 262–269.

[13] L. Yisi, O. Sourina, and M. K. Nguyen, "Real-time eeg-based emotion recognition and its applications," in *Transactions on computational science XII*. Springer, 2011, pp. 256–277.

[14] L. Gil and H. Tal, "Age and gender classification using convolutional neural networks," in *IEEE Conf. on Computer Vision and Pattern Recognition (CVPR) workshops*, June 2015.

[15] C. B. Ng, Y. H. Tay, and B. M. Goi, "Vision-based human gender recognition: A survey," *Pacific Rim International Conferences on Artificial Intelligence*, pp. 335–346, 2012.

[16] S. El-Kaddouhi, A. Saaidi, and M. Abarkan, "A new robust face detection method based on corner points," *International Journal of Software Engineering and Its Applications*, vol. 8, no. 11, pp. 25–40, 2014.

[17] H. V. Lakshmi and S. PatilKulakarni, "Segmentation algorithm for multiple face detection in color images with skin tone regions using color spaces and edge detection techniques," *International journal of computer theory and engineering*, vol. 2, no. 4, pp. 1793–8201, 2010.

[18] V. S. Bhat and D. Pujari, "Face detection system using hsv color model and morphing operations." International Journal of Current Engineering and Technology, 2013, pp. 200–204.

[19] Z. S. Tabatabaie, R. W. Rahmat, N. Udzir, and E. Kheirkhah, "A hybrid face detection system using combination of appearance-based and feature-based methods," *International Journal of Computer Science and Network Security*, vol. 9, no. 5, pp. 181–185, 2009.

[20] X. Pang, F. Gao, and D. Ma, "A face detection method via combination of skin color detection and visual attention theory," *Journal of Information and Computational Science*, vol. 11, p. 14, 2014.

[21] M.-H. Yang, D. J. Kriegman, and N. Ahuja, "Detecting faces in images: A survey," *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, vol. 24, no. 1, pp. 34–58, 2002.

[22] M. Berbar, H. M. Kelash, and A. Kandeel, "Faces and facial features detection in color images," in *Geometric Modeling and Imaging–New Trends, 2006*. IEEE, 1993, pp. 209–214.

[23] G. Yang and T. S. Huang, "Human face detection in a complex background," *Elsevier Pattern recognition*, vol. 27, no. 1, pp. 53–63, 1994.

[24] S. Y. Lee, Y. K. Ham, and R. H. Park, "Recognition of human front faces using knowledge-based feature extraction and neurofuzzy algorithm," *Pattern recognition*, vol. 29, no. 11, pp. 1863–1876, 1996.

[25] Y.-B. Lee and S. Lee, "Robust face detection based on knowledge-directed specification of bottom-up saliency," *Etri Journal*, vol. 33, no. 4, pp. 600–610, 2011.

[26] S. Devadethan, G. Titus, and S. Purushothaman, "Face detection and facial feature extraction based on a fusion of knowledge based method and morphological image processing," in *Emerging Research Areas: Magnetics, Machines and Drives (AICERA/iCMMD), 2014 Annual International Conference on*. IEEE, 2014, pp. 1–5.

[27] K. Vij and Y. Singh, "Enhancement of images using histogram processing techniques," *Int. J. Comp. Tech. Appl*, vol. 2, no. 2, pp. 309–313, 2009.

[28] B. S. Min, D. K. Lim, S. J. Kim, and J. H. Lee, "A novel method of determining parameters of clahe based on image entropy," *International Journal of Software Engineering and Its Applications*, vol. 7, no. 5, pp. 113–120, 2013.

[29] A. Z. Kouzani, F. He, and K. Sammut, "Commonsense knowledge-based face detection," in *Intelligent Engineering Systems, 1997. INES'97. Proceedings., 1997 IEEE International Conference on*. IEEE, 1997, pp. 215–220.

[30] G. A. Patil and S. A. Patil, "face detection using rgb ratio model," *International journal of computer Application*, pp. 18–20, 2014.

[31] R. Bin-Abdul, A. Nusirwan, K. C. Wei, and J. See, "Rgb-h-cbcr skin colour model for human face detection," *Faculty of Information Technology, Multimedia University*, 2007.

[32] D. Ghimire and J. Lee, "A robust face detection method based on skin color and edges," *Journal of Information Processing Systems*, vol. 9, no. 1, pp. 141–156, 2013.

[33] P. Saikia, G. Janam, and M. Kathing, "Face detection using skin colour model and distance between eyes," *International Journal*, vol. 1, no. 3, pp. 102–105, 2012.

[34] S. Anila and N. Devarajan, "Simple and fast face detection system based on edges," *International Journal of Universal Computer Sciences*, vol. 1, no. 2, pp. 54–58, 2010.

[35] M. K. Rashmi and S. Rohini, "Algorithm and Technique on various edge detection: A survey," *Signal and Image Processing An International Journal (SIPIJ)*, vol. 4, no. 3, 2013.

[36] Y. Suzuki and T. Shibata, "An edge-based face detection algorithm robust against illumination, focus, and scale variations," in *Signal Processing Conference, 2004 12th European*. IEEE, 2004, pp. 2279–2282.

[37] M. Modil and F. Macwan, "Face detection approaches: A survey," *International Journal of Innovative Research in Science, Engineering and Technology*, 2014.

[38] M. Tkal, A. Odi, and A. Koir, "The impact of weak ground truth and facial expressiveness on affect detection accuracy from time-continuous videos of facial expressions," *Information Sciences*, vol. 249, pp. 13–23, 2013.

[39] T. B. Moeslund, A. Hilton, and V. Krüger, "A survey of advances in vision-based human motion capture and analysis," *Computer vision and image understanding*, vol. 104, no. 2, pp. 90–126, 2006.

[40] Y. Suzuki and T. Shibata, "Multiple-clue face detection algorithm using edge-based feature vectors," in *Acoustics, Speech, and Signal Processing, 2004. Proceedings.(ICASSP'04). IEEE International Conference on*, vol. 5. IEEE, 2004, pp. V–737.

[41] C. Saravanan and M. Surender, "Algorithm for face matching using normalized cross-correlation," *International Journal of Engineering and Advanced Technology (IJEAT) ISSN*, pp. 2249–8958, 2013.

[42] T. Sakai, M. Nagao, and S. Fujibayashi, "Line extraction and pattern detection in a photograph," *Pattern recognition*, vol. 1, no. 3, pp. 233–248, 1969.

[43] A. L. Yuille, P. W. Hallinan, and D. S. Cohen, "Feature extraction from faces using deformable templates," *International journal of computer vision*, vol. 8, no. 2, pp. 99–111, 1992.

[44] N. N. Dawoud, B. B. Samir, and J. Janier, "Fast template matching method based on optimized metrics for face localization," in *Proceedings of the International MultiConference of Engineers and Computer Scientists*, vol. 1, 2012.

[45] Y. Zhu and F. Cutu, "Face detection using half-face templates," *Journal of Vision, ISSN*, pp. 1534–7362, 2003.

[46] D. Dubey and S. Lecturer, "Face detection using genetic algorithm and neural network," *International Journal of Science and Advanced Technology*, vol. 1, no. 6, pp. 104–109, 2011.

[47] M. Yang, J. Crenshaw, B. Augustine, R. Mareachen, and Y. Wu, "Adaboost-based face detection for embedded systems," *Elsevier Computer Vision and Image Understanding*, vol. 114, no. 11, pp. 1116–1125, 2010.

[48] A. Javed, "Face recognition based on principal component analysis," *International Journal of Image, Graphics and Signal Processing (IJIGSP)*, vol. 5, no. 2, p. 38, 2013.

[49] A. Al-Marghilani, "Artificial neural network in face detection human on digital image," *American Journal of Applied Sciences*, vol. 10, no. 10, p. 1234, 2013.

[50] Y. Li, S. Gong, J. Sherrah, and H. Liddell, "Support vector machine based multi-view face detection and recognition," *Image and Vision Computing*, vol. 22, no. 5, pp. 413–427, 2004.

[51] Z.-L. Huang, Z.-M. Lu, F.-X. Yu, and Y. Zhang, "A fast face detection scheme utilizing hsv-based skin color model with kl transform," *Information Technology Journal*, vol. 13, no. 1, p. 183, 2014.

[52] H. Abdi and L. J. Williams, "Principal component analysis," *Wiley Interdisciplinary Reviews: Computational Statistics*, vol. 2, no. 4, pp. 433–459, 2010.

[53] L. C. Paul and A. Al-Sumam, "Face recognition using principal component analysis method," *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*, vol. 1, no. 9, pp. pp–135, 2012.

[54] H. T. Ngo, R. Gottumukkal, and V. K. Asari, "A flexible and efficient hardware architecture for real-time face recognition based on eigenface," in *VLSI, 2005. Proceedings. IEEE Computer Society Annual Symposium on*. IEEE, 2005, pp. 280–281.

[55] O. N. Al-Allaf, "Review of face detection systems based artificial neural networks algorithms," *The International Journal of Multimedia & Its Applications (IJMA)*, vol. 6, no. 1, pp. 1–16, 2014.

[56] H. M. El-Bakry, "Face detection using fast neural networks and image decomposition," *Neurocomputing*, vol. 48, no. 1, pp. 1039–1046, 2002.

[57] H. Li, Z. Lin, X. Shen, J. Brandt, and G. Hua, "A convolutional neural network cascade for face detection," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, 2015, pp. 5325–5334.

[58] H. A. Rowley, S. Baluja, and T. Kanade, "Neural network-based face detection," *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, vol. 20, no. 1, pp. 23–38, 1998.

[59] P. Viola and M. J. Jones, "Robust real-time face detection," *International journal of computer vision*, vol. 57, no. 2, pp. 137–154, 2004.

[60] Z. Jun-chang and Z. Yi, "Human face detection based on genetic algorithm," in *Information Science and Engineering (ICISE), 2010 2nd International Conference on*. IEEE, 2010, pp. 1–4.

[61] L. C. Ho, H. Marsyita, and D. S. Tanko, "Integrated face and facial components detection," *International Conference on Computational Intelligence, Modelling and Simulation*, pp. 65–69, 2015.

[62] B. Wu, H. Ai, C. Huang, and S. Lao, "Fast rotation invariant multi-view face detection based on real adaboost," in *Automatic Face and Gesture Recognition, 2004. Proceedings. Sixth IEEE International Conference on*. IEEE, 2004, pp. 79–84.

[63] N. K. El-Abbadi and A. A. A. Qazzaz, "Detection and segmentation of human face," *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 1, no. 1, pp. 90–94, 2015.

[64] M. Verma, P. Rani, and H. Kundra, "A hybrid approach to human face detection," *international Journal of Computer Applications (0975–8887) Volume*, 2010.

[65] S. Tripathi, V. Sharma, and S. Sharma, "Face detection using combined skin color detector and template matching method," *International Journal of Computer Applications*, vol. 26, no. 7, pp. 5–8, 2011.

[66] M. Niazi and S. Jafari, "Hybrid face detection in color images," *IJCSI International Journal of Computer Sciences Issues*, vol. 7, pp. 367–373, 2010.

[67] K. M. Alajel, W. Xiang, and J. Leis, "Face detection based on skin color modeling and modified hausdorff distance," in *Consumer Communications and Networking Conference (CCNC), 2011 IEEE*. IEEE, 2011, pp. 399–404.

[68] J. Zhang and Y. Li, "A novel approach of face detection based on skin color segmentation and svm," in *Advanced Research on Automation, Communication, Architectonics and Materials*, ser. Advanced Materials Research, vol. 225. Trans Tech Publications, 6 2011, pp. 437–441.

[69] S. Kherchaoui and A. Houacine, "Face detection based on a model of the skin color with constraints and template matching," in *Machine and Web Intelligence (ICMWI), 2010 International Conference on*. IEEE, 2010, pp. 469–472.

[70] Z. Li, L. Xue, and F. Tan, "Face detection in complex background based on skin color features and improved adaboost algorithms," in *Progress in Informatics and Computing (PIC), 2010 IEEE International Conference on*, vol. 2. IEEE, 2010, pp. 723–727.

[71] P. J. Phillips, P. J. Rauss, S. Z. Der *et al.*, *FERET (face recognition technology) recognition algorithm development and test results*. Army Research Laboratory, 1996.

[72] P. J. Phillips, H. Moon, S. Rizvi, P. J. Rauss *et al.*, "The feret evaluation methodology for face-recognition algorithms," *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, vol. 22, no. 10, pp. 1090–1104, 2000.

[73] P. Belhumeur and D. Kriegman, "The yale face database," *URL: http://cvc. yale. edu/projects/yalefaces/yalefaces. html*, vol. 1, no. 2, p. 4, 1997.

[74] S. Milborrow, J. Morkel, and F. Nicolls, "The MUCT landmarked face database," *Pattern Recognition Association of South Africa*, vol. 201, no. 0, 2010.

[75] A. Martinez and R. Benavente, "The ar database," CVC Technical Report, Tech. Rep., 1998.

[76] M. Grgic, K. Delac, and S. Grgic, "Scface–surveillance cameras face database," *Multimedia tools and applications*, vol. 51, no. 3, pp. 863–879, 2011.

[77] T. I. Dhamecha, P. Verma, M. Shah, R. Singh, and M. Vatsa, "Annotated crowd video face database," in *IEEE 2015 International Conference on Biometrics (ICB)*, 2015, pp. 106–112.

[78] B. F. Klare, E. Taborsky, A. Blanton, J. Cheney, K. Allen, P. Grother, A. Mah, M. Burge, and A. K. Jain, "Pushing the frontiers of unconstrained face detection and recognition: Iarpa janus benchmark a," *algorithms*, vol. 13, p. 4, 2015.

[79] G. Zapryanov, D. Ivanova, and I. Nikolova, "Automatic white balance algorithms for digital still cameras–A comparative study," *Information Technologies and Control*, pp. 16–22, 2012.

[80] K. Koh, H. Marsyita, and R. Abdul, "Optimal combination of color components for skin detection," *4th International Conference on Artificial Intelligence with Applications in Engineering and Technology*, no. 1, pp. 171–176, 2014.

[81] Z.-W. Zhang, M.-H. Wang, Z.-M. Lu, and Y. Zhang, "A skin color model based on modified glhs space for face detection," *changes*, vol. 8, no. 9, pp. 10–11, 2014.

[82] K. H. Ghazali, J. Ma, and R. Xiao, "An innovative face detection based on skin color segmentation," *International Journal of Computer Applications*, vol. 34, no. 2, pp. 6–10, 2011.

[83] A. Ford and A. Roberts, "Colour space conversions," *Westminster University, London*, vol. 1998, pp. 1–31, 1998.

[84] R. C. Gonzalez and R. E. Woods, "Digital image processing 3rd edition, beijing: Publishing house of electronics industry," 2007.

[85] C. Solomon and T. Breckon, *Fundamentals of Digital Image Processing: A practical approach with examples in Matlab*. John Wiley & Sons, 2011.

[86] S. Bhardwaj and A. Mittal, "A survey on various edge detector techniques," *Procedia Technology*, vol. 4, pp. 220–226, 2012.

[87] E. R. Dougherty, R. A. Lotufo, and T. I. S. for Optical Engineering SPIE, *Hands-on morphological image processing*, vol. 71.

LIST OF PUBLICATIONS

Salka, T. D., Hanafi, M., Mashohor, S. and Syed, S. M., "Large Variability Surveillance Camera Face Database". Seventh International Conference on Computational Intelligence, Modelling and simulation, page 86-90. http://doi.org/10.1109/CIMSim.2015.21, (2015).

Salka, T. D., Hanafi, M., Mashohor, S. and Syed, S. M., "Face Detection for Surveillance Systems Application". 4th International Conference on Advances in Engineering Sciences and Applied Mathematics. page 76-79, 2015.

Chin, H. L., Hanafi, M., and Salka, T. D. "Integrated Face and Facial Components Detection." Seventh International Conference on Computational Intelligence, Modelling and simulation, Published by IEEE, 65–69. http://doi.org/10.1109/CIMSim.2015.16.

Salka, T. D., Hanafi, M., Mashohor, S. and Syed, S. M., "Dynamic Face Detection on Images Captured by Surveillance Camera" Journal of Machine Vision and Applications. (Q2, 1.351 Impact factor) (2016) Submitted.

UNIVERSITI PUTRA MALAYSIA
STATUS CONFIRMATION FOR THESIS/PROJECT REPORT AND COPYRIGHT
ACADEMIC SESSION: 2016/2017

TITLE OF THE THESIS/PROJECT REPORT:
INTEGRATED FACE DETECTION APPROACH FOR FAR IMAGE APPLICATION
NAME OF STUDENT: TANKO DANIEL SALKA

I acknowledge that the copyright and other intellectual property in the thesis/project report belonged to Universiti Putra Malaysia and I agree to allow this thesis/project report to be placed at the library under the following terms:

1. This thesis/project report is the property of Universiti Putra Malaysia.
2. The library of Universiti Putra Malaysia has the right to make copies for educational purposes only.
3. The library of Universiti Putra Malaysia is allowed to make copies of this thesis for academic exchange.

I declare that this thesis is classified as:

*Please tick(✓)

☐	CONFIDENTIAL	(contain confidential information under Official Secret Act 1972).
☐	RESTRICTED	(Contains restricted information as specified by the organization/institution where research was done).
☐	OPEN ACCESS	I agree that my thesis/project report to be published as hard copy or online open acces.

This thesis is submitted for:

☐	PATENT	Embargo from _____(date) until _____(date).

Approved by:

_____
(Signature of Student)
New IC No/Passport No.:A04444993

Date:

_____
(Signature of Chairman of Supervisory Committee)
Name: **Marsyita Binti Hanafi, Ph.D.**

Date:

[Note: If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization/institution with period and reasons for confidentially or restricted.]