UNIVERSITI PUTRA MALAYSIA

FACIAL AGE RANGE ESTIMATION USING GEOMETRIC RATIOS AND HESSIAN-BASED FILTER WRINKLE ANALYSIS

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FACIAL AGE RANGE ESTIMATION USING GEOMETRIC RATIOS AND HESSIAN-BASED FILTER WRINKLE ANALYSIS

By

HUSNIZA BINTI RAZALLI

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

October 2016

DEDICATION

This thesis is dedicated to me and all my heroes

My parents who taught me that if I make a wish and work hard, it would come true.

To my husband and my kids who taught me to be brave and patient.

To my family, my good friends and my teachers

Without whom none of my success will be possible

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

FACIAL AGE RANGE ESTIMATION USING GEOMETRIC RATIOS AND HESSIAN-BASED FILTER WRINKLE ANALYSIS

By

HUSNIZA BINTI RAZALLI

OCTOBER 2016

Chair: Associate Prof. Rahmita Wirza O.K. Rahmat, PhD

Faculty: Computer Science and Information Technology

Human Face holds important amount of information such as expression, identity, gender and age. The vast majority of people are able to easily recognize human traits like emotional states, where they can tell if the person is happy, sad or angry from face. However, estimating person's age from face image is a challenging task. The facial age estimation method has recently gained attention from the computer vision and computer graphic community due to its applications as well as the challenges in the development process.

Traditionally, researchers using numerous of ratios obtained from extracted facial features landmark points to measure facial age. Most of those points are obtained from publicly facial aging database. Although the estimation result promising, the method still have limitation because it's work with manual calibration to detect, to extract all the landmark point to estimate human facial age.

Lately, many researchers combine facial features geometric ratios with facial skin texture to estimates human facial age range. Facial skin texture was obtained based on the lines that form wrinkles in the facial area. Based on literature study, a technique often used for facial wrinkles analysis is obtained based on Canny Edge Detector. However, it produces inconsistence performance because edge detector only detect wrinkle boundaries rather than the wrinkle itself.

In this thesis, a new automatic facial age range estimation method using geometric ratios and wrinkle analysis is proposed. The geometric ratios are based on combination of facial features distances and angles distribution between selected face features using minimum

extracted facial features landmark points. The Hessian-Based Filter is used to enhance wrinkle analysis for age range estimation method.

In addition, this research proposed a new algorithm to measure face region end points which also used as landmark points derived from Ideal Frontal Symmetry and Proportion of the Face to estimation age range. The age range was classified using SVM and Multi-SVM classifier and the performance evaluation was tested on FG-NET database.

Experiments for each phase in the research framework were qualitatively and quantitatively evaluated. The overall findings show that the proposed method is significantly increase the estimation rate with 92% of accuracy compared to previous methods. The proposed method also able to estimate age of person with no hair or hair that covers part of the forehead. Besides, this work is also successfully implemented in real-time face tracking application because using fully automatic extraction and localization approach.

Abstrak tesis yang dikemukakan oleh Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

AGGARAN LINGKUNGAN UMUR MUKA MENGUNAKAN PELBAGAI NISBAH GEOMETRI DAN ANALISIS KEDUT BEDASARKAN PENYARINGAN HESSIAN

Oleh

HUSNIZA BINTI RAZALLI

OKTOBER 2016

Pengerusi: Profesor Madya Rahmita Wirza O.K. Rahmat, PhD

Fakulti: Sains Komputer dan Teknologi Maklumat

Wajah manusia mengandungi pelbagai maklumat penting seperti Emosi, identiti, jantina dan umur. Emosi seseorang dapat dikesan dengan mudah hanya berpandukan ekspresi wajah contohnya jika seseorang itu gembira, sedih atau marah. Walau bagaimanapun, menganggar umur hanya berdasarkan imej wajah adalah satu tugas yang mencabar. Anggaran umur manusia berdasarkan imej wajah adalah satu pendekatan yang baru diperkenalkan dalam bidang visi komputer dan grafik komputer kerana kewujudan pelbagai applikasi komputer serta cabaran yang dihadapi untuk membangunkannya.

Secara tradisional, penyelidik seringkali menggunakan sejumlah besar ukuran nisbah yang diperolehi daripada titik tanda yang diekstrak daripada ciri-ciri muka untuk menganggar umur manusia daripada imej wajah. Kebanyakannya titik-titik tanda ciri-ciri muka ini diperolehi dari pangkalan data imej penuaan muka umum. Walaupun hasil anggaran titik-titik tanda muka menghasilkan keputusan anggaran umur muka yang baik, kaedah ini masih mempunyai had kerana ia bekerja dengan proses manual untuk mengesan dan mengestrak titik-titik tersebut untuk digunakan bagi menganggar umur wajah manusia.

Pada masa ini, ramai penyelidik yang mengabungkan orientasi jarak titik-titik tanda ciri-ciri muka bersama dengan testur muka untuk menghasilkan ukuran anggaran umur muka yang lebih tepat. Testur muka yang diperolehi adalah berdasarkan kedutan yang terbentuk di kawasan muka. Bepandukan kajian literatur, teknik yang sering digunakan untuk memperolehi kedutan muka adalah berdasarkan garisan sempadan Canny. Walau bagaimanapun, ia menghasilkan prestasi tidak konsisten kerana pengesan sempadan hanya mengesan sempadan kedut bukannya kedut itu sendiri.

Di dalam tesis ini, algoritma bagi mengira anggaran umur muka secara automatik menggunakan pelbagai nisbah geometri ciri-ciri muka dan analisa kedut berasaskan penapis Hessian diperkenalkan. Nisbah nisbah geometri ini adalah berdasarkan kepada gabungan jarak ciri-ciri wajah dan sudut pengagihan antara ciri-ciri wajah yang dipilih menggunakan titik-titik tanda muka yang telah diekstrak. Penapis Hessian digunakan bagi meningkatkan keputusan analisis kedutan bagi mengangar umur wajah seseorang.

Di samping itu, kajian ini telah memperkenalkan satu algoritma baru untuk mengukur titik-titik sempadan kawasan muka yang diperolehi daripada Perkadaran Simetri Bahagian Hadapan Muka Paling Ideal yang juga digunakan sebagai titik tanda untuk menganggar umur muka. Julat umur diklasifikasikan menggunakan pengkelasan SVM dan Multi-SVM dan penilaian prestasi untuk setiap algoritma telah diuji mengunakan pangkalan data FG-NET.

Eksperimen bagi setiap fasa dalam rangka kerja penyelidikan ini dinilai secara kualitatif dan kuantitatif. Hasil penyelidikan menunjukkan kaedah yang telah dicadangkan di dalam kajian ini telah meningkatkan kadar penganggaran lingkungan umur wajah dengan 92% jumlah ketepatan kadar anggaran umur berbanding kaedah sebelumnya dan dapat menganggarkan umur seseorang tanpa rambut atau rambut yang meliputi sebahagian dahi. Selain itu, kaedah menganggar lingkungan umur wajah ini juga berjaya diimplimentasikan ke dalam program aplikasi komputer dengan masa nyata kerana menggunakan pendekatan pengeluaran dan penyetempatan secara automatik sepenuhnya.

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I certify that a Thesis Examination Committee has met on 6 October 2016 to conduct the final examination of Husniza Binti Razalli on her thesis entitled "Facial Age Range Estimation Using Geometric Ratios and Hessian-Based Filter Wrinkle Analysis" 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 Doctor of Philosophy.

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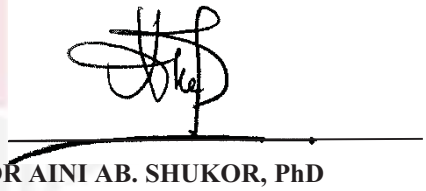

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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I hereby confirm that:

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LIST OF ABBREVIATIONS

HCI	Human Computer Interaction
PDM	Point Distribution Model
AAM	Active Appearance Model
SVM	Support Vector Machine
LAR	Least Angle Regression
LTP	Local Ternary Patterns
LBP	Local Binary Patterns
SVR	Support Vector Regression
PCA	Principle Component Analysis
VPF	Variance Projection Function
MIPF	Mean Integral Projection Function
CPF	Combined Projection Function
DCT	Discrete Cosines Transformation
FF	Frangi Filter
MRA	Magnetic Resonance Angiography
FOV	Field of View
HHF	Hybrid Hessian Filter
HBF	Hessian-Based Filter
AARE	Automated Age Range Estimation
Multi-SVM	Multi-Level Support Vector Machine
2D	Two Dimensional
AdaBoost	Adaptive Boosting
FG-NET	Face and Gesture Recognition Research Network
GUI	Graphical User Interface
PSO	Particle Swarm Optimization
GR	Geometric Ratios
ROI	Region of Interest
MRA	Magnetic Resonance Angiography

CHAPTER 1

INTRODUCTION

Human faces are characteristically associated with unique identities such as gender, race, age cluster, skin colours, etc. Human perception studies conclude that attributes derived from facial appearance such as emotional state, attractiveness, perceived age, etc. tend to significantly influence interpersonal behaviour. Hence, human faces have been closely studied in computer vision and psychophysics for many years with the objective of characterizing the many factors that bring appearance variations and subsequently finding information related to an individual facial appearances.

In recent years, a new dimension has been added to the problems of face recognition. Age as a characteristic related to facial appearance is being progressively studied. There has been a growing interest in problems such as face recognition across ages, automatic age estimation from face images, appearance prediction across aging, etc. The research initiatives pertaining these problem have reached a thoughtful stage and it is essential to rationalise future research on this topic in order to make a significant impact on the many usual applications that benefit from solving this problem (Haider, Bashir, Sharif, Sharif, & Wahab, 2014; Huerta, Fernández, Segura, Hernando, & Prati, 2015).

This chapter presents a brief background on the use of facial appearance in estimating human facial age range based on facial image and deliberate the estimation method in computer graphics, vision and visualization. This is then followed by the motivation of the research interests in automatic extraction, localization and estimation approach, and methods that utilize facial features geometric ratios and face wrinkle analysis using facial image. This chapter will then present to you the details of the research problems, research significance, objectives, and the scope of this research. Finally, this chapter will be concluded with the organization of the overall thesis.

1.1 Background

The increasing integration of technology to everyday lives makes it essential to develop intelligent systems that can evaluate the human profile and address the specific needs of individuals in a personalized manner. Age information is a useful source of information, which can have a range of applications including internet safety of the youth, targeted advertisements, and surveillance. For example, information in regards to aging population statistics on customers of a certain product, service or program would be very useful to be applied in Real-time Application for Customer Satisfaction Index (Azman et al., 2015). This application is based on facial expression recognition system, which is used to capture a person's facial expression. The main idea of this system is to capture customers' facial expressions while using a product or services and act as an assessment tool to evaluate customer satisfaction with subjective evaluation (questionnaire) to understand customers' facial expressions. Comparing to the ordinary way of getting customers' feedback through a survey or interview, the facial expression recognition system will enable product or services seller to get customers' feedback immediately,

which eventually helps product or services seller to save time. The possible use of age estimation and classification in this application is seen to have the potential of enhancing existing parameters in Human Computer Interaction (HCI) to new.

There are many possible real world applications where age estimation can be used. Age estimation from facial images is a challenging problem since aging is a personalized process and it is also affected by many factors. Though there is such potential demand for application usage, age estimation via facial images remains a difficult problem due to different rate of aging process contributed by not only genetic factors but also other factors like living style, health and place of stay (Haider et al., 2014; Huerta et al., 2015). In certain cases, differences in appearance between adjacent age groups are negligible, causing difficulties in the process of age estimation (Panis, Tsapatsoulis, Cootes, & Lanitis, 2015). Based on the current research works in this area, it is still not within reach of an expected creditable level of performance.

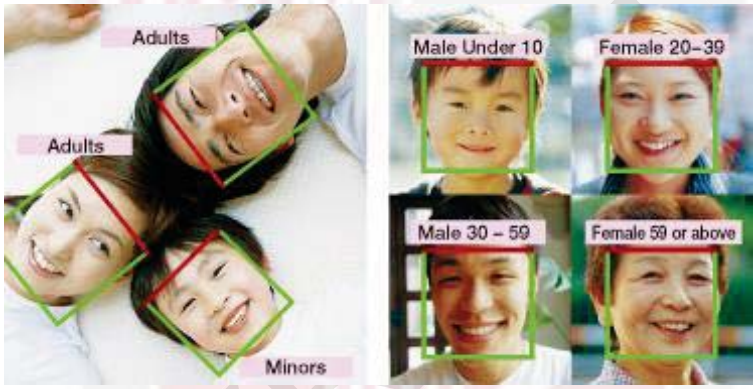

Figure 1.1: Sample age estimation applications currently existing in the market
[Image refer from: www.omron.com]

Age estimation can be handled as either a classification problem or a regression problem depending on the application. Applications requiring the exact age to be known, such as Internet safety, will be a regression problem. Applications that do not require the exact ages to be known, such as targeted advertisement, can be regarded as classification problems (Erkin, 2014).

Age estimation based on age classification of humans using their facial images is a part of the biometric research field. Biometric systems use behavioral and physiological characteristics to recognize individuals. Soft biometric traits like age, gender, ethnicity, height and weight in combination with hard biometric traits can be used to enhance the performance of biometric systems. This research concentrates on estimating age based on age classification process, where it can also be known as age range estimation method.

1.2 Motivation and Importance of the Research

The aging process affects the appearance of the human's face in many ways. The changes that occur are related to face shapes, facial features orientation, and changes in the face texture. Some characteristics of face shape and facial features orientation appear only in people of a certain age and change during the aging process (Petra, Miroslav, & Markus, 2011). Changes in skin texture usually occur in adulthood. According to the previous work done by (Geng, Fu, & Smith-Miles, 2010), changes in the face that occur during aging and growth are:

- chin becomes more prominent,
- cheeks spread over a larger area,
- facial characteristics increase and cover the interstitial spaces,
- head falls backwards, reducing the free space on the surface of the skull,
- facial hair becomes thicker and changes color,
- skin color changes, skin becomes thinner, darker, less elastic and more leathery, and
- wrinkle appears, underchin appears, cheeks sag and bags under the eyes appear.

Based on all these changes, the age of a person can be determined.

Human facial age range estimation can be defined in many ways. This research will however focuses on the age estimation and classification based on two-dimensional images of people's faces. Age estimation and classification is done using face anthropometry based on facial features geometric ratio and facial wrinkle analysis.

For the purpose of this research, definitions of basic terms are given. Age range estimation is used to classify images of those children and adults. Children are defined as people from age 0 to 18 and adults are defined as people from age 19 and above. Age estimation in this research is defined as determining the age of a person based on biometric features, precisely referring to the basis of two-dimensional images of human face Facial landmarks can be defined as the standard reference points on the face used by scientists to recognize the face, or in this case, predict the age of a person. Anthropometry is the science dealing with measurements of the size, weight, and proportions of the human body (Medical Dictionary, 2015). Therefore, facial anthropometry deals with measurements of the size and proportions of human face, whereas wrinkle texture deals with facial wrinkle that occur during aging.

The main motivation of this research is to design an algorithm that classifies humans facial image into children and adults based on facial features geometric ratios and hessian-based wrinkle analysis and then extends the process into another level by classifying these two groups into another age range groups for the use of detecting illegal content, especially potential pedophile images. The proposed algorithm can also assist in detecting missing people across ages or years. This research will identify the characteristic points of the face necessary in classifying face images, while identifying the most appropriate model for age range estimation. Furthermore, a new algorithm for age classification will be developed. All detection and extraction processes, which were defined in this research will be performed automatically in order to implement the method into real-time face tracking application. Accuracy of the algorithm will be

calculated and compared with the accuracy of existing algorithms. The performance of the face tracking application with age range estimation method will also be evaluated.

By combining age estimation with real-time face tracking application, this research will be able to enhance these technologies into deep learning performance evaluation and monitoring environment. For example, Real-time User Satisfaction Index Application (Azman et al., 2015), which currently detects user expression to measure user satisfaction index in cooperate agencies, is able to be implemented by combining age estimation method in the real-time tracking application. This proposed intelligent system is able to improve the classification efficiency while measuring user satisfaction index.

1.3 Problem Statement

Facial features landmark points are important key points in this research in order to develop a new algorithm to estimate human face age for face tracking application. However, measuring crucial facial features landmark points has become a prominent subject when dealing with automatic localization process. However, prior works thus far have used too many facial features landmark points in age estimation method, which involves complex process in obtaining the point when dealing with automated extraction (Izadpanahi & Toygar, 2014), (Dehshibi & Bastanfard, 2010). However, from the literature studied shown in Table 1.1, not all extracted points are useful to calculate the geometric ratios for age estimation method.

Table 1.1: Landmark points that used in previous work

References	Number of Landmarks Points
(Kleinberg & Siebert, 2012)	38
(Takimoto, Kuwano, Mitsukura, Fukai, & Fukumi, 2007)	28
(Txia & Huang, 2009)	28
(Ramanathan & Chellappa, 2006b)	24
(Köstinger, Wohlhart, Roth, & Bischof, 2011)	21
(Izadpanahi & Toygar, 2014)	16
(Dehshibi & Bastanfard, 2010)	8

Furthermore, inaccurate detected points will distract the structure of the proposed method and might reduce the accuracy of the new algorithm, hence influencing the end application, which is constructed based on the proposed new algorithm. The difficulties to measure the points can automatically divert facial age range estimation to wrong result if the method is unable to locate upper region of the face end points or hair growth starting point when dealing with individuals with no hair or hair that covers part of the forehead as describe in Figure 1.2. There can also be difficulties to measure the left and right face region end points when measuring those who are covered with hijab or scarf.

Certainly, these issues involve many processes in order to meet the objectives of detecting accurate face region end points.

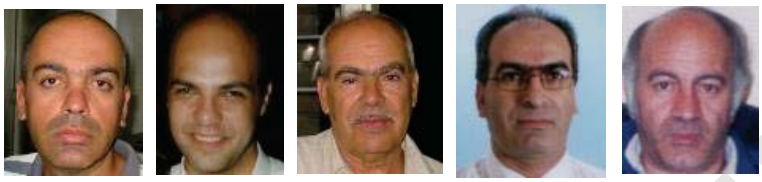

Figure 1.2: Sample face image from FG-NET datasets of individual with no hair

Figure 1.3: Sample face image from FG-NET datasets of individual with face region was covered part of the forehead

Previous studies have focused on multilevel preprocessing and complicated functionalities to estimate age range, which involves complex computation, where more time are needed to detect, extract and process numerous facial features landmark points and ratios. Based on this, those available age estimation methods that are currently available in the market, can be inappropriate to implement real-time face tracking application. By minimizing the involvement of image processing work particularly used to obtain optimal measurement of geometrical ratios of the facial image, it will reduce processing time in the proposed tracking application. Earlier works have also emphasized on facial features distance as geometric ratio to estimate age range, which had produced inconsistent performances.

In order to get higher accuracy in age estimation method and to work with face tracking application, the selected additional ratios should be computationally efficient. Involvement of additional ratios such as angle between facial features will be able to help achieve higher levels of accuracy (Dehshibi & Bastanfard, 2010). Moreover, performance improvement is achieved through introduction of new feature representation into previous researches and implementation of the new age estimation framework.

According to reviewed literatures, changes in texture of human face (skin changes, wrinkles, skin elasticity, etc.) are mostly influenced by many factors and changed from person to person across ages. Since global and local age estimation is considered in this research, these changes are appropriate to be obtained as other feature ratios. Also, in current time, face texture changes such as wrinkles have become important factors in everyday life for most women and men, which has direct influences on the reliability of age estimation algorithm. However, the current wrinkle detection methods are confused with edge detection methods. As mention in previous works, edge is the border between

two areas while wrinkle is a line that is either darker or lighter than their neighboring wrinkle lines. Therefore, edge detection methods such as Canny and Sobel are not suitable for wrinkle detection due to the fact that it produces pixel boundaries, not a wrinkle (Ng, Yap, Costen, & Li, 2015a).

In conclusions of all the details mentioned above, these are the identified technical problems that need further research and solutions:

i) According to the study of earlier works (Dehshibi & Bastanfard, 2010; Izadpanahi & Toygar, 2014; Köstinger et al., 2011; Ramanathan & Chellappa, 2006a), too many facial features landmark points were used in age classification and estimation method and not all extracted points are useful to calculate age based on geometric ratios.

ii) The difficulties to measure and locate upper, lower, left and right points of the face region using automatic processing especially when the detection of the overall face region deals with several limited circumstances discussed earlier (Dahlan, Mashohor, Rahman, & Adnan, 2013).

iii) Earlier works only focused on facial features distance as geometric ratio to estimate age range, which produced inconsistent performances (Dehshibi & Bastanfard, 2010; Izadpanahi & Toygar, 2014). In order to work with computational efficiency, to increase the accuracy of the method and to work with face tracking application, additional ratios should be added.

iv) In current practices (Dehshibi & Bastanfard, 2010; Izadpanahi & Toygar, 2014), wrinkles detection methods produce only pixel boundaries by adaptation of edge detection algorithms. This means that, certain pixels boundaries are not always a representation of wrinkles. To produce a better representation of wrinkles the existing wrinkles analysis algorithm need to be improved.

1.4 Research Objectives

The main objective of this thesis is to design an algorithm to estimate facial age range using the facial features geometric ratios with automatic extraction of facial features landmark points and new facial wrinkle analysis. This algorithm also applicable to implement in face tracking application.

Hence, to achieve the main aims, the following objectives are formulated:

1. To extract optimum facial features landmark points and ratios using frontal view facial image datasets to measure human facial age range.
2. To obtain face region end points or sub landmark points using Ideally Frontal Symmetry and Proportion of the face information for age range estimation.
3. To estimate human facial age range by combining the facial features distances, facial features angles distribution and face shape elliptical ratio as geometric ratios from the input face image for different person with different age.
4. To enhance wrinkles analysis for age range estimation method by constructing a new method to extract wrinkle from input face image using Hessian-Based Filter.

1.5 Research Scope

The contribution of this thesis to the advancement towards this proposed work is to enhance the accuracy and minimize the computational complexity of automated detecting system by proposing robust and less computationally demanding methods of facial feature extraction and representation. Thus, the scope of this work is mainly limited to feature-based schemes.

This thesis proposes designing and implementing a facial age range method estimation which concentrates on estimating facial age range using geometric ratios and new wrinkle analysis techniques based on automatic face detection and facial features landmark points extraction and localization. With the aim of identifying and addressing the challenges that are associated with such automatic face tracking application, the typical input of this method must be limited to several scope such as:

- The sample image must contain facial image with neutral or normal expression
- The face in the image comprises with a rotation tolerance of ±15° of head pose and is in full frontal view within the image.
- The sample image should contain normal face, which means the person in the image should be in a normal facial feature orientation appearance or in other words, the person does not have any facial disorder.
- The sample are not wearing any facial accessories such as spectacles, nose rings, studs and jewelleries.

The publicly aging database FG-NET is used for experimenting and testing the proposed method,-A video, which contains face images with maximum frontal view is captured to test the developed tracking application.

Sample faces that are chosen for the proposed methods is in normal appearance and has symmetry facial features orientation within ±10 pixels range annotated on the captured image. Additionally, facial features like eyes, nose, mouth and face shape on the face images should not be occluded with any interference in order to achieve higher test accuracy.

1.6 Thesis Organization

A brief background and motivation of the research are presented in this chapter, as well as the research problem, significances, objectives, and research scope. The remaining chapters of this thesis are organized as follows:

Chapter 2 introduces a review on the state of the art literature of age estimation method implemented in previous works. Then, it presents the brief explanation in particular about the technique that uses facial features geometric ratios and facial wrinkle analysis in age estimation research work.

Chapter 3 describes the overall research framework and discussion on the proposed framework for facial age estimation using face images. In addition, this chapter explains

about the preliminary study, data acquisition, pre-processing of data, datasets used and brief details on the rest of this research's work.

Chapter 4 describes the details of facial features landmark point extraction and localization using ideally frontal symmetry and proportion of the face. The chapter starts with an introduction, the proposed methodology of the algorithm, implementation, results, discussion, the advantages and limitations of the algorithm.

Chapter 5 presents the design of the new algorithm in calculating human facial age estimation based on geometric ratios. The chapter starts with an introduction, the proposed methodology of the new algorithm, implementation, results, discussion, the advantages and limitations of the new algorithm.

Chapter 6 discusses the design of facial age estimation method based on Hessian-Based Filter wrinkle analysis. The chapter starts with an introduction, the proposed methodology of the algorithm, implementation, results, discussion, the advantages and limitations of the algorithm.

Chapter 7 describes the design of automatic face tracking with embedded age range estimation algorithm application, which was developed as an implementation platform for the proposed method designed during this research.

Chapter 7 concludes the whole research, highlighting the contributions, which also includes the overall evaluation process. This chapter ends with a proposal of recommendations for future work.

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