DEVELOPMENT OF FACIAL EMOTION RECOGNITION SYSTEM USING A MODIFIED PARTICLE SWARM OPTIMIZATION TECHNIQUE

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Development of Facial Emotion Recognition System Using a Modified Particle Swarm Optimization Technique

by

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TABLE OF CONTENTS

DECLARATION OF THESIS		i
AKNOWLEDGEMENT		ii
TABLE OF CONTENTS		iv
LIST OF TABLES		viii
LIST OF FIGURES		ix
LIST OF ABBREVIATIONS		xi
ABSTRAK (BM)		xiii
ABSTRACT (ENGLISH)		xiv
CHAPTER 1	INTRODOCTION	
1.1	Overview	1
1.2	Problem Statement	3
1.3	Research Objectives	6
1.4	Research Methodology	7
1.5	Thesis Layout	9
CHAPTER 2	LITERATURE REVIEW ON FACIAL EMOTION RECOGNITION	
2.1	Introduction	12
2.2	The Six Universal Basic Emotions	14
2.3	Measurement of Facial Expressions	15
2.4	Feature Extraction Methods	17
2.5	Classification Approaches	19
2.5.1	Neural Networks Classification Methods	19

2.5.2	Genetic Algorithm Classification Methods	23
2.5.3	Other Classification Methods	25
2.6	Real-Time Systems for Facial Emotion Recognition	27
2.7	Applications	30
2.8	Summary	33
CHAPTER 3	MODIFIED PSO ALGORITHM FOR FACIAL EMOTION RECOGNITION	
3.1	Introduction	34
3.2	Overview of Particle Swarm Optimization Algorithm	35
3.2.1	Choosing Stopping Condition for PSO	41
3.2.2	Basic PSO Parameters	42
3.3	Modification of PSO for Facial Emotion Recognition	43
3.3.1	Domains of FPs	44
3.3.2	Search Space and its Dimension	45
3.3.3	Particles and their Distances and Velocities	46
3.3.4	Objective Function	46
3.3.5	Guided Particle Swarm Optimization Algorithm	48
3.4	Implementation of GPSO as a Programming Library	51
3.4.1	Domain Class	53
3.4.2	Particle Class	54
3.4.3	Swarm Class	57
3.5	Summary	60

CHAPTER 4	REAL-TIME SYSTEM FOR FACIAL EMOTION RECOGNITION	
4.1	Introduction	61
4.2	Offline Systems versus Real-Time Systems	62
4.3	Overview of Lucas-Kanade Optical Flow Algorithm	65
4.4	System Implementation	69
4.5	Results and Discussion	73
4.6	Fault-Tolerance Evaluation	77
4.7	Interfacing with a Humanoid Robot	79
4.8	Summary	73
CHAPTER 5	COMPARATIVE ANALYSIS OF GPSO WITH NEURAL NETWORK AND GENETIC ALGORITHM	
5.1	Introduction	85
5.2	Emotion Recognition using Artificial Neural Network	85
5.2.1	Backpropagation Algorithm	87
5.2.2	Network Architecture	88
5.2.3	Activation Function	89
5.2.4	Network Parameters	90
5.2.5	Data Preparation	92
5.2.6	Implementation, Training and Testing	95
5.2.7	Results and Discussion	98
5.3	Emotion Recognition using Genetic Algorithm	101
5.3.1	GA Processes	102
5.3.2	Genes and Chromosomes	104
5.3.3	Objective Function	105

5.3.4	GA Operators	108
5.3.5	GA Parameters	112
5.3.6	Data Preparation	115
5.3.7	Implementation and Testing	116
5.3.8	Results and Discussions	117
5.4	Comparison of GPSO System with BPNN and GA Systems	119
5.5	Summary	122
CHAPTER 6	CONCLUSION AND RECOMMENDATIONS	
6.1	Conclusions	124
6.2	Recommendations	127
REFERENCES		130
APPENDIX A:	PROGRAMING CODE FOR THE GPSO ALGORITHM	141
APPENDIX B:	PROGRAMING CODE FOR THE GPSO-BASED EMOTION RECOGNITION SYSTEM	147
APPENDIX C:	PROGRAMING CODE FOR THE BPNN-BASED EMOTION RECOGNITION SYSTEM	157
APPENDIX D:	PROGRAMING CODE FOR THE GA-BASED EMOTION RECOGNITION SYSTEM	166
LIST OF PUBLICATIONS		181

LIST OF TABLES

Table No.	Title	Page No.
2.1	Examples of approaches that used Neural Networks for facial emotion recognition.	22
2.2	Examples of approaches that used GA for feature extraction or facial emotion classification	25
2.3	Examples of approaches that attempted real-time facial emotion recognition.	29
3.1	Values of GPSO Parameters Used	50
3.2	Attributes of the Particle Class	54
3.3	Attributes of the Swarm Class	57
4.1	Percentage recognition success rates using GPSO system for each of the six basic emotions taken over 25 subjects of different backgrounds	74
4.2	Speed of Emotion Detection Using GPSO Algorithm	76
4.3	Percentage recognition success rates of GPSO system with 2% noise data	77
4.4	Percentage recognition success rates of GPSO system with 5% noise data	78
4.5	Percentage recognition success rates of GPSO system with the Humanoid Robot Integrated	82
5.1	Percentage Recognition Success Rates Obtained Using the BPNN Method	99
5.2	Speed of Emotion Detection Using BPNN	100
5.3	GA Parameters	115
5.4	Percentage Recognition Success Rates Obtained Using the GA Method	118
5.5	Speed of Emotion Detection Using GA	119

LIST OF FIGURES

Figure No.	Title	Page No.
1.1	Illustrations of Facial Points (FPs)	8
1.2	Data Flow Diagram of the Methodology	9
2.1	Samples of the Six Basic Universal Emotions	14
3.1	Examples of Social Network Structures	37
3.2	Steps of the Global best PSO algorithm	38
3.3	Flowchart of the Global best PSO algorithm	38
3.4	Illustrations of Facial Points (FPs) and their Domains	45
3.5	Cluster of Swarms	47
3.6	Steps of the GPSO algorithm	49
3.7	Data Flow Diagram of the GPSO algorithm	50
3.8	Class diagram for the GPSO algorithm implementation	53
3.9	Get RandomPoint method of the Domain Class	54
3.10	Initialize method of the Particle Class	55
3.11	UpdateVelocity method of the Particle Class	56
3.12	UpdatePosition method of the Particle Class	57
3.13	Initialize method of the Swarm Class	58
3.14	ComputeEculidean method of the Swarm Class	58
3.15	Objective method of the Swarm Class	58
3.16	Move method of the Swarm Class	59
4.1	Subject with luminous physical markers expressing emotions	63
4.2	Small cut-out from a sample video data file obtained after digitization	63
4.3	How FPs are specified in real time on a video stream	65

4.4	Optical Flow illustration	66
4.5	Data flow diagram of the GPSO-based emotion recognition system	70
4.6	Happy emotion identified by the emotion recognition system	71
4.7	*OnIdle* method of the GPSO-based emotion recognition system	73
4.8	Percentage success rates for GPSO based emotion recognition system	75
4.9	Humanoid Robot mounted with a wireless video camera and integrated with the emotion recognition software system	79
4.10	Humanoid Experimental Setup	81
5.1	Summarized Back-Propagation Algorithm	87
5.2	Structure of the BPNN used for the experiment	88
5.3	Graph of the Sigmoid function	89
5.4	Minimum error achieved with different number of hidden neurons	91
5.5	Steps involved in the BPNN experiment	93
5.6	User-Interface of the BPNN-based system	96
5.7	Snap-Shot of the end of an output file generated by the BPNN system	97
5.8	Percentage success rates for BPNN based emotion recognition system	99
5.9	Flow chart of basic genetic algorithm	102
5.10	Basic Genetic Algorithm	103
5.11	FPs, Domains, Genes and Chromosomes	105
5.12	Cluster of Populations of Chromosomes for a Multi-Objective GA	106
5.13	Example of sector allocation on roulette wheel	108
5.14	Pseudo code for the reproduction process using roulette wheel	109
5.15	User-Interface of the GA-based Emotion Recognition System	116
5.16	Percentage success rates for GA based emotion recognition system	118
5.17	Comparison of classification among GPSO, BPNN and GA methods	120
5.18	Speed of Emotion Recognition for GPSO, BPNN and GA methods	121

LIST OF ABBREVIATIONS

AANN	Auto-Associative Neural Network
AdaBoost	Adaptive Boosting
AFFEX	Affective Expressions Scoring System
AI	Artificial Intelligence
ANN	Artificial Neural Network
AU	Action Unit
BPNN	Back Propagation Neural Network
C#	A programming langauge
CCTV	Closed-Circuit Television
CNN	Convolutional Neural Network
DLL	Dynamic Link Library
E2E	Environment to Environment
EEG	Electroencephalography
EMFACS	Emotion Facial Action Coding System
EMG	Electromyography
et al.	and others
FACS	Facial Action Coding System
FACSAID	Facial Action Coding System Affect Interpretation
FCM	Fuzzy C-means
FETS	Facial Emotion Tree Structures
FP	Facial Point
fps	Frames per Second
GA	Genetic Algorithms
GP	Genetic Programing

GPSO	Guided Particle Swarm Optimization
HCI	Human-Computer Interaction
HMM	Hidden Markov's Model
KNN	K-Nearest Neighbor
LGF	Localized Gabor Filter
LK	Lucas-Kanade
LSA	Latent Semantic Analysis
MLP	Multi Layer Perceptron
MPEG	Moving Picture Experts Group
NN	Neural Network
OOP	Object-Oriented Programming
PCA	Principal Component Analysis
PLSA	Probabilistic Latent Semantic Analysis
PNN	Probabilistic Neural Networks
PSO	Particle Swarm Optimization
RPMS	Remote Patient Monitoring System
SNHC	Synthetic Natural Hybrid Coding
SVM	Support Vector Machine
VLE	Virtual Leaning Environment

Pembangunan Sistem Pengecaman Emosi Wajah Menggunakan kaedah ubahsuai Kelumpuk Partikel Terpandu

ABSTRAK

Pengecaman emosi wajah secara automatik merupakan bidang penyelidikan yang sangat aktif masa ini. Ini disebabkan oleh kaedah berinterkasi dengan komputer secara tradisional menggunakan papan kekunci, tetikus dan skrin sudah ketinggalan zaman jika dibandingkan dengan kemajuan teknologi komputer dan penggunaannya yang meluas dalam tugas-tugas harian. Bagi suatu interaksi yang baik diantara manusia dengan komputer, komputer yang dihasilkan pada masa akan datang perlu mempunyai kepintaran sendiri untuk memulakan tindakan yang sewajarnya dan bukan hanya menunggu arahan yang jelas daripada pengguna. Bagi mencapai matlamat ini, komputer mesti berupaya untuk melihat emosi wajah di mana ia merupakan kaedah utama yang membolehkan manusia meluahkan keadaan fikiran mereka dan juga memberikan isyarat dan penjelasan semasa interaksi. Walaupun terdapat banyak pendekatan untuk pengecaman emosi wajah dihasilkan, namun ianya menggunakan teknik-teknik pemprosesan imej yang kompleks, menjadikannya kurang sesuai untuk aplikasi masa-nyata. Di dalam tesis ini, Titik-titik Muka (*FPs*) yang diletakkan di atas wajah subjek, digunakan sebagai ciri-ciri yang dianalisis bagi tujuan mengenal pasti emosi. Pendekatan ini digabungkan dengan algoritma Aliran Optik Lucas-Kanade untuk mengesan kedudukan Titik-titik Muka semasa beroperasi, telah berjaya mengelakkan daripada keperluan untuk pra-pemprosesan dan mengurangkan masa pengiraan yang diperlukan untuk mengekstrak ciri-ciri daripada imej urutan wajah. Satu algoritma yang dinamakan Optimasi Kelumpuk Partikel Terpandu (*GPSO*) adalah dicadangkan sebagai teknik terbaik yang menganalisis kedudukan masa larian *FPs* untuk mengenal pasti emosi yang dinyatakan oleh subjek. Satu perisian pengecaman emosi masa-nyata kemudiannya dibina menggunakan algoritma *GPSO* sebagai pengecam. Perisian tersebut merakam gambar subjek secara langsung sebagai masukan dan apabila *FPs* dinyatakan semasa aliran tersebut, ia akan mengklasifikasikan emosi yang dipamerkan oleh subjek dalam setiap bingkai, dan seterusnya memaparkan hasil keluaran. Prestasi perisian telah diuji menggunakan 25 subjek dari latar belakang etnik yang berbeza dan berjaya megecam enam emosi asas, iaitu gembira, sedih, terkejut, benci, takut dan marah dengan betul; dengan kadar ketepatan pengecaman purata 86.17% pada kadar pemprosesan purata 31.58 bingkai sesaat. Sebagai satu cara untuk terus menilai kaedah *GPSO*, dua teknik Kecerdasan Buatan (*AI*) lain telah diteroka; iaitu Rangkaian Saraf Propagasi Belakang (*BPNN*) dan Algoritma Genetik (*GA*). Dalam setiap kes, perisian pengecaman emosi dilaksanakan semula menggunakan setiap kaedah ini dan diuji dengan set data daripada 25 subjek yang sama. Secara keseluruhan, kaedah *GPSO* merupakan teknik yang terbaik dalam setiap kes. Akhir sekali, sebagai satu cara untuk menerapkan perisian bagi menghasilkan automasi robot yang dapat mengenali emosi dan mungkin menawarkan beberapa perkhidmatan kepada warga tua dan orang kurang upaya; perisian tersebut telah diintegrasi kepada robot humanoid. Penyusunan ini dilakukan menggunakan kamera tanpa wayar yang diletakkan di atas kepala robot untuk merakam dan menghantar rakaman wajah subjek kepada perisian tersebut. Perisian mengenal pasti emosi dalam masa-nyata, seterusnya menghantar hasil keluaran kepada robot. Robot tersebut kemudian melaksanakan aksi-aksi yang telah diaturcarakan berdasarkan emosi yang telah dikenalpasti. Perisian tersebut menghasilkan prestasi yang baik dalam senario ini.

Development of Facial Emotion Recognition System Using a Modified Particle Swarm Optimization Technique

ABSTRACT

Automatic facial emotion recognition has become a very active research area in recent years. The reason for this interest in the subject is because the traditional means of interacting with computers, namely keyboard, mouse and screen, have become outdated when compared to the advancement of computer technology and its wider usage in everyday tasks. For a better human-computer interaction, future computers need to have the intelligence to initiate appropriate actions on their own rather than waiting for explicit commands from users. To achieve this, computers must be able to perceive facial emotions, which is the primary means through which humans express their state of mind and also provide cues and explanations during interactions. While many different approaches for facial emotion recognition have been proposed, many of them involved computationally expensive image processing techniques, making them unsuitable for real-time applications. In this thesis, Facial Points (FPs), which are specified on the face of a subject, are themselves proposed to be used as features that are analyzed for the purpose of identifying emotions. This approach, combined with the Lucas-Kanade optical flow algorithm that is used to keep track of the positions of the FPs at run-time, succeeded in eliminating the need for pre-processing and cutting down the computational time required to extract features from image sequences of the face. An algorithm named, Guided Particle Swarm Optimization (GPSO), is proposed as a novel technique that analyzes the run-time positions of the FPs to recognize the emotion expressed by the subject. A real-time emotion recognition software is then developed using the GPSO algorithm as the classifier. The software takes a live video stream of the subject as input and once the FPs are specified on the stream; it correctly classifies the emotion expressed by the subject in each frame and instantaneously displays the result. The performance of the software was evaluated by testing it with 25 subjects of different ethnic backgrounds and was found to correctly recognize the six basic emotions, namely happy, sad, surprise, disgust, fear and anger; achieving an average recognition success rate of 86.17% at an average processing rate of 31.58 frames per second. As a way of further evaluating the GPSO method, two other AI techniques were explored; namely Backpropagation Neural Network (BPNN) and Genetic Algorithm (GA). In each case, the emotion recognition software was implemented using each of these methods and tested with the same set of data from 25 subjects. The GPSO method was found to be the overall best in each case. Finally, as a way of investigating the feasibility of embedding the software to create an autonomous robot that can recognize emotions and possibly offer some service to the elderly and the disabled; the software was integrated with a humanoid robot. In this arrangement, the wireless camera on the head on the robot captures and transmits the video stream of the subject's face to the software. The software identifies the emotion in real time and transmits the result to the robot. The robot then performs some pre-programmed actions corresponding to the recognized emotion. The software was found to still perform well in this scenario.

CHAPTER 1

INTRODUCTION

1.1 Overview

An old adage in the native *Hausa* language of this researcher goes thus: "*Labarin zuciya a tambayi fuska*". Translated into English, this proverb means, if you wish to know what is going on in the mind (of someone), just look at the face. This underscores the significance of the human face as the revealer of the state of mind among its many other functions. As eloquently put by Pantic and Patras (Pantic & Patras, 2006), "the human face is involved in an impressive variety of different activities. It houses the apparatuses for speech production (mouth, tongue and teeth) as well as the majority of our sensory apparatuses: eyes, ears, mouth and nose, allowing the bearer to see, hear, taste and smell". In addition to these biological functions, the human face also provides a number of social signals essential for interpersonal communication. It exposes the identity of the bearer, whether he or she is attractive or not and in what emotional or mood he or she is. Human utterances are normally accompanied by appropriate facial expressions and cues that clarify whether what is spoken is meant to be a joke or serious. Similarly, observing the facial expressions of a listener to someone speaking can often reveal the listener's current focus of attention, his comprehension, his agreement or disagreement, etc. In short, a human being uses his face to regulate his interactions with the environment and other persons in his vicinity (Russell & Dols, 1997). A study by Mehrabian (Mehrabian, 1968), indicates that, whether a listener to a speech feels liked or disliked towards the speech depends only for 7% on the actual spoken word, for 38% on vocal utterances (how the words were spoken), while facial expressions determine this feeling by 55%. This means

facial expression is the largest determining factor on impressiveness or otherwise of speech listeners. It is no wonder therefore, that the terms “face-to-face” and “interface” are very common when discussing about issues relating to interactions, whether human-to-human or human-to-machine interactions. It is equally not surprising that facial emotion recognition has become a very active research area for people from a variety of research interests such as computer vision, human-computer-interaction (HCI), medical engineering, robotics, etc.

This surge in research interest on facial emotion recognition is not unconnected with the present information technology era, where computer and the Internet have become so embedded in the fabric of our daily lives. This technology is used for communication, for work, for shopping, for seeking new information, and for entertainment. There is therefore the recognition that HCI needs to be made more natural and seamless and one way of doing that is to make computers to be intelligent enough to perceive the emotional state of the human user. The Present HCI designs usually involve the conventional interface devices like keyboard, mouse, and visual displays, and assume that the human will be explicit, unambiguous and fully attentive while controlling information and command flow. This kind of interfacing and categorical computing, also referred to as machine-centered (Pantic, Pentland, Nijholt, & Huang, 2006), works well for context-independent tasks like purchasing an item online. What is needed for computers of the future is the human-centered HCI design where computers can anticipate and understand the human natural way of interaction using voice, facial expressions, and gestures. This is the challenge today, to move from machine-centered to human-centered HCI, and researchers from different backgrounds

have been working towards this goal. This research is also geared towards contributing to solve this challenge.

The goal of this research is to design an efficient Artificial Intelligence (AI) technique that can be used to implement a software system that can recognize the basic human emotions. Such a system must not only be able to recognize facial emotions, but it must do so accurately and very fast so that it works in real-time. The idea is that such a system can eventually be embedded into a robot that will in turn provide assistance to the elderly and physically impaired people who may not be able to express their need except through facial expressions and emotions. In this thesis, a detail literature survey carried out to understand the various methods that other researchers have proposed for emotion recognition has been documented. A new algorithm, which is based on Particle Swarm Optimization (PSO) algorithm, has been proposed. The proposed algorithm was then used to implement a real-time software for facial emotion recognition. The performance of the software was evaluated not only by testing it with human subjects, but also by comparing the results with what was obtained after re-implementing the software with other popular AI methods, namely ANN and GA.

1.2 Problem Statement

The emotion recognition problem is a well known problem and has been studied by many researchers with different backgrounds over the past fifteen years. The hypothesis is that if computers can be equipped with the intelligence to recognize the emotional state of the human user, then human-computer interaction can be much improved from its current machine-centered to the more natural user-centered approach.

Instead of using mouse and keyboards to issue commands, facial expressions and gestures can be used. Moreover, instead of waiting for the user to issue commands, the computer itself can anticipate and initiate actions based on its own observations of the state of the user. For example, a social welfare robot designed to assist an elderly person can initiate first-aid support or call an ambulance if necessary based on its reading of the state of the person it is monitoring. A car can automatically pull off the road when it observes that the driver is drowsy, etc. These are some of the premises of having a computer system that can recognize human emotions.

Over the recent past, many techniques and methods have been proposed for solving the emotion recognition problem. However, many of the methods proposed involve some computationally expensive image pre-processing techniques, such as using Gabor filter to normalize images before some kind of template matching techniques are used to classify the images. Many other classification techniques that were reported, used neural networks as the underline method, which in turn involve elaborate data collection and training stages. Therefore, despite the many good emotion recognition and classification rates that have been reported, the reality is that many of them were achieved using methods and techniques that can only be applied in offline systems. The problem with offline systems is that they have few and limited applications. For example, a team of detective police officers trying to unravel the identity of people involved in a crime can benefit from an offline recognition or tracking system. The act has already been committed and the scenes of the incident are recorded by CCTV cameras, so that the data is available and is complete. There is enough time in this case to do any pre-processing and training necessary before the real classification and identification can begin. So an offline system is very adequate and appropriate in

this scenario. However, when an application requires instantaneous response, such as in human-computer interaction or social welfare robot, then in that case there is no room for pre-processing or an extensive data collection and training session. In this case only a real-time system will suffice. This is precisely the problem that this research effort is intended to tackle – to develop a system that can recognize human facial emotion in real-time. This means the system must work with live video stream as input rather than still images or recorded video clips. Such a system must use features (or feature extraction methods) that are light in terms of computation time. Moreover, such a system must employ efficient classification algorithms and techniques that can identify and classify emotions at the real-time speed of at least 30 frames per second, which is the standard for video display of image sequences (Wang, Claypool, & Zuo, 2001).

In summary, the problem which this research is intended to solved can be summarized as follows:

i) Today's computer systems lack the ability to perceive the emotional state of the human user. Such emotion perception ability is necessary in order to create a more natural human-computer interaction which is becoming increasingly important given the wide application of computer systems in everyday tasks.

ii) Although there has been a lot of research efforts to come up with computer systems that can perceive human emotions, most of the techniques reported are computationally expensive, thus rendering the resulting system as in adequate for real-time applications.

iii) The few research efforts that attempted to produce a real-time system are mostly designed to recognize only a sub-set of the six basic human emotions.

iv) There is a need to develop a system that is efficient enough to work in real-time and at the same time have the ability to classify all the six basic emotion with good accuracy rate.

1.3 Research Objectives

The Objectives of this research are as follows:

i) To develop an effective data collection and feature extraction technique that is fast and accurate enough for real-time classification of emotions.

ii) To develop an efficient algorithm that can be used to detect the six basic facial emotions, namely happy, sad, surprise, disgust, anger and fear. The algorithm must be able to identify and classify emotions in an efficient and fast manner such that it can be used in applications that require real-time results.

iii) To develop a computer software using the algorithm developed in (ii) above that can be used to recognize the six basic emotions. The software must work with live video stream of a human subject as input and must be able to identify and classify the emotions in real time so that the result is immediately displayed on the screen as the subject expresses different emotions.

iv) To integrate the software developed in (iii) above into a robot so that the robot acts and behaves according to the emotions recognized by the software, effectively creating an emotion-controlled robot.

v) To evaluate the performance of the proposed system with respect to processing speed and accuracy of emotion classification.

1.4 Research Methodology

The methodology adopted for this research consists of the following components and approaches:

i) To undertake an extensive literature review of past research work in the field of emotion recognition and interpretation with a view to identify the various methods and techniques already proposed. The study should identify the successes and failures or weaknesses of the documented methods and techniques. In this study, emphasis should be given to those methods that rely on visual means of getting input rather than those that rely on physiological signals or bio-sensors. The vision-sensing approach is considered to be more compatible with the objective of developing an autonomous emotion-controlled robot as the bio-sensor approaches usually require a sensing devise to be placed on the body of the subject, thus making the observer to be physically tied to the subject.

ii) To employ efficient methods for obtaining input from the face of the subject. The overall objective is to have a system that works in real-time, receiving inputs and instantaneously displaying the output. Therefore, computationally expensive image

and video processing methods that seek to use the image of the whole face must be avoided. Instead, a few relevant Facial Points (FPs) as shown in Figure 1.1 should be used as features. The hypothesis is that by studying the relative positions of these facial points alone as the subject expresses different emotion, it should be possible to identify what emotion is being expressed at each point in time.

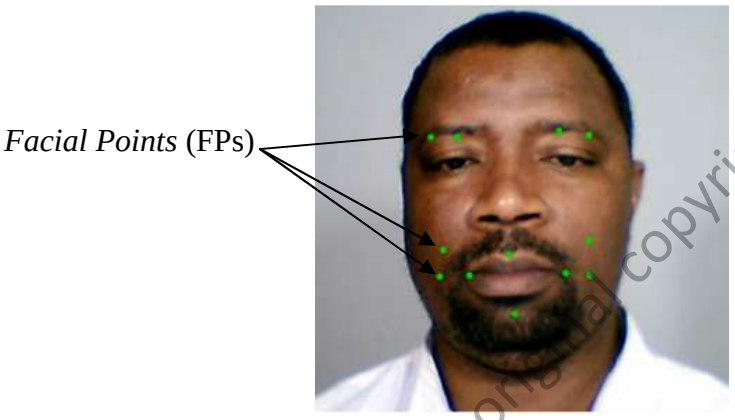

Figure 1.1: Illustrations of Facial Points (FPs)

iii) To explore the various computational intelligence methods that have been proposed recently, such as PSO algorithm, Artificial Neural Networks (ANN) and Genetic Algorithms (GA) to find out which of them can be applied (perhaps after some modifications) to analyze the input obtained in (ii) above and identify the emotion expressed. Comparison should be made to find out which of these methods gives the best results both in terms of accuracy of identification and classification of emotions as well as the speed at which the classification is achieved.

iv) To use the algorithm developed in (iii) above to develop a real-time software for facial emotion recognition. The software should be tested with human subjects to ascertain its accuracy of classification as well as its processing speed in frames per second. Moreover, the performance of the software should be compared against

similar software developed using other popular algorithms as a way of proving its efficiency. Finally, the software should be integrated with a robot to show how it can be used in controlling the behavior of the robot.

Figure 1.2 shows a data flow diagram summarizing the research methodology.

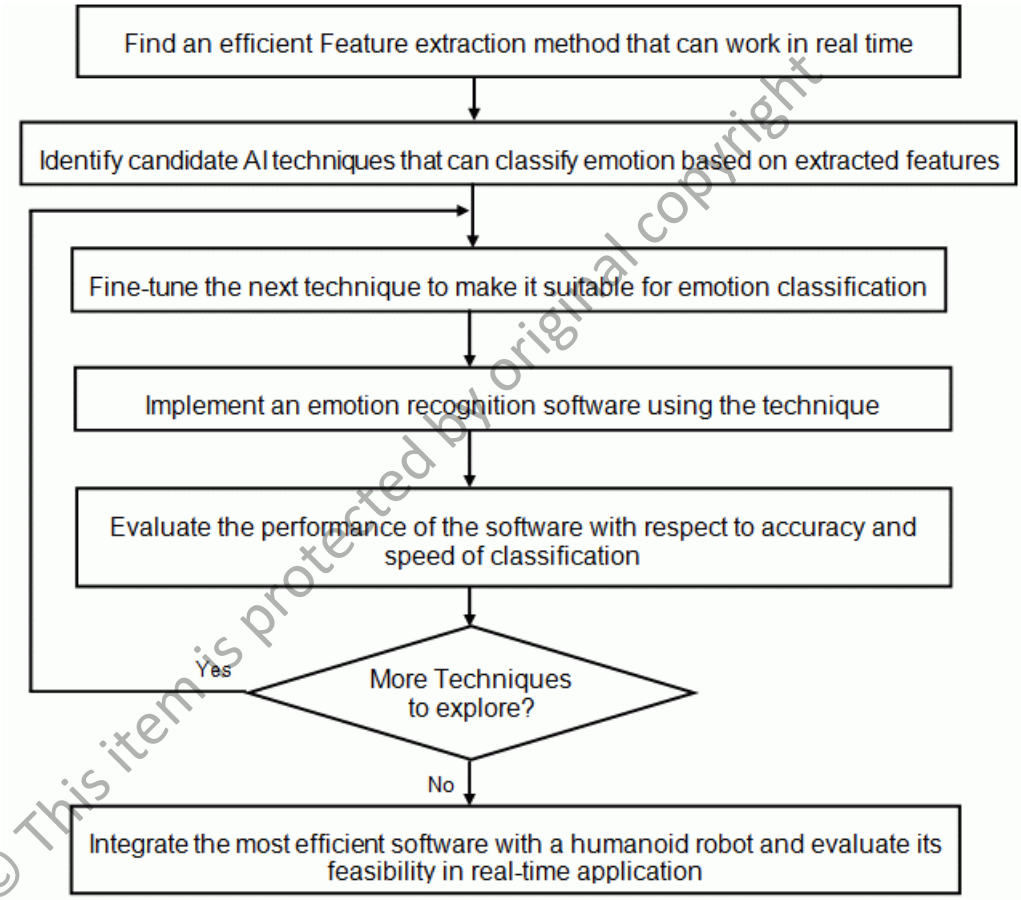

Figure 1.2: Data Flow Diagram of the Methodology

1.5 Thesis Layout

Chapter 1 gives an overall introduction to the thesis, highlighting the importance of facial emotion recognition as an active and important research area. The specific