



Faculty of Manufacturing Engineering

HUMAN SPONTANEOUS EMOTION DETECTION SYSTEM

Radin Puteri Hazimah binti Radin Monawir

Master of Science in Manufacturing Engineering

2018

HUMAN SPONTANEOUS EMOTION DETECTION SYSTEM

RADIN PUTERI HAZIMAH BINTI RADIN MONAWIR

**A thesis submitted in fulfillment of the requirements for the degree of Master of
Science in Manufacturing Engineering**

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

DECLARATION

I declare that this thesis entitled “Human Spontaneous Emotion Detection System” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature :

Name :

Date :

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature :

Supervisor Name :

Date :

DEDICATION

To my dearest family.

ABSTRACT

Having smart computerized system which can understand and instantly gives appropriate response to human is the utmost motive in human and computer interaction (HCI) field. It is argued either HCI is considered advance if human could not have natural and comfortable interaction like human to human interaction. Besides, despite of several studies regarding emotion detection system, current system mostly tested in laboratory environment and using mimic emotion. Realizing the current system research lack of real life or genuine emotion input, this research work comes up with the idea of developing a system that able to recognize human emotion through facial expression. Therefore, the aims of this study are threefold which are to enhance the algorithm to detect spontaneous emotion, to develop spontaneous facial expression database and to verify the algorithm performance. This project used Matlab programming language, specifically Viola Jones method for features tracking and extraction, then pattern matching for emotion classification purpose. Mouth feature is used as main features to identify the emotion of the expression. For verification purpose, the mimic and spontaneous database which are obtained from internet, open source database or novel (own) developed databases are used. Basically, the performance of the system is indicated by emotion detection rate and average execution time. At the end of this study, it is found that this system is suitable for recognizing spontaneous facial expression (63.28%) compared to posed facial expression (51.46%). The verification even better for positive emotion with 71.02% detection rate compared to 48.09% for negative emotion detection rate. Finally, overall detection rate of 61.20% is considered good since this system can execute result within 3s and use spontaneous input data which known as highly susceptible to noise.

ABSTRAK

Mempunyai sistem komputer yang boleh memahami dan memberikan tindak balas yang sewajarnya dalam kadar yang cepat adalah motif utama dalam bidang perhubungan manusia dan komputer. Menjadi perdebatan adakah hubungan manusia dan komputer ini dikira cukup maju sekiranya komputer tidak mampu mempunyai interaksi yang natural dan selesa seperti interaksi antara manusia dengan manusia. Selain itu, walaupun banyak kajian berkaitan pengesanan emosi manusia, kebanyakan sistem kini dikaji dan diuji dalam makmal dan tidak dijalankan menggunakan data sebenar dengan emosi sebenar. Oleh itu, tujuan utama kajian ini adalah menghasilkan sistem yang mampu mengenali emosi manusia melalui ekspresi wajah, menyediakan pangkalan data ekspresi wajah yang spontan serta menguji kemampuan sistem tersebut. Projek ini menggunakan bahasa pemrograman Matlab, secara tepatnya, kaedah Viola Jones untuk mengesan serta mengekstrak keluar ciri wajah dan menggunakan teknik memadankan corak untuk tujuan pengklasifikasian emosi. Mulut merupakan ciri wajah yang digunakan untuk mengenal pasti emosi. Bagi mengesahkan prestasi sistem ini, pangkalan data mimik dan spontan didapati dari internet, sumber terbuka dan penghasilan sendiri telah digunakan. Secara asasnya prestasi sistem diukur dengan peratusan ketepatan mengenal emosi serta masa yang diambil untuk memproses imej. Di akhir kajian, didapati sistem ini sesuai untuk mengenal pasti ekspresi spontan (63.28%) berbanding mimik (51.46%). Bahkan prestasi sistem lebih baik apabila menguji pangkalan data emosi positif iaitu 71.02% kadar pengesanan berbanding emosi negatif, hanya 48.09% kadar pengesanan emosi. Akhirnya, kadar pengenalan emosi bagi keseluruhan sistem adalah 61.20% dan ini dikira bagus kerana sistem ini boleh mendapatkan hasil dalam 3 saat dan menggunakan input spontan yang mana ianya diketahui mempunyai banyak gangguan.

ACKNOWLEDGEMENTS

Alhamdulillah, all praise to Allah whose blessing and guidance helps me upon this thesis completion. First and foremost, I would like to thank Dr Fairul Azni bin Jafar for being marvelous supervisor along my degree journey. His guidance and support mean a lot for my study. Secondly, I would like to thank UTeM for providing me MyBrain UTeM which is very helpful for my research. Next, I would like to show my gratitude to my dearest family, especially my husband, Zulhasnizam bin Hasan, my mom and late father, Asiah binti Hatta and Radin Monawir bin Radin Hadi Munir, and my mother in law, Kintan binti Jafar. Your continuous support, motivation, understanding and prayers always enlighten my journey. Last but not least, special thanks to my friends, including lab mates who always encourage and aid me in this research.

TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
LIST OF TABLES	vi
LIST OF FIGURES	vii
LIST OF APPENDICES	x
LIST OF ABBREVIATIONS	xi
LIST OF PUBLICATIONS	xii
 CHAPTER	
1. INTRODUCTION	1
1.1 Background of Study	1
1.2 Motivation	2
1.3 Problem Statement	3
1.4 Research Question	4
1.5 Hypothesis	4
1.6 Objectives	5
1.7 Scopes and Limitations	5
1.8 Thesis Outline	7
 2. LITERATURE REVIEW	8
2.1 Emotion in General	8
2.2 Emotion Detection Methods	11
2.2.1 Physiological Emotion Detection	11
2.2.2 Speech Emotion Detection	12
2.2.3 Visual Emotion Detection	16
2.2.4 Minor and Hybrid Emotion Detection Method	22
2.3 Facial Emotion Detection	24
2.3.1 Facial Images Acquisition Stage	25
2.3.2 Facial Extraction Stage	26
2.3.3 Emotion Classification Method	30
2.4 Comparative Studies and Selected Method	31
2.5 Summary	34
 3. RESEARCH METHODOLOGY	35
3.1 Overview	35
3.2 Emotion Detection Techniques Selection	37
3.2.1 Pilot Study	37
3.3 Algorithm Enhancement	47
3.3.1 Image Acquisition and Extraction	48
3.3.2 Emotion Classification	50
3.4 Experimental Set Up: Database Development	56

3.5	Verification Methods	66
3.6	Summary	66
4.	RESULT AND DISCUSSION	68
4.1	System Performance Verification	68
4.1.1	Negative versus Positive Emotion Detection Percentage	69
4.1.2	Mimic versus Spontaneous Database Performance	74
4.1.3	Overall System Performance	77
4.1.4	Mean Execution Time	80
4.2	Challenges in Spontaneous Emotion Detection	82
4.2.1	Individual Unique Way of Expressing Emotion	82
4.2.2	Unexpected Spontaneous Reaction	86
4.3	Summary	89
5.	CONCLUSION AND FUTURE RECOMMENDATION	90
5.1	Conclusion	90
5.2	Improvement and Recommendation	91
	REFERENCES	94
	APPENDICES	104

LIST OF TABLES

TABLE	TITLE	PAGE
3.1	Database Summarization.	63
4.1	Facial Expression of The Pilot Study Participants.	71
4.2	Negative Emotion Brainwaves Signals and its Facial Expression in The Pilot Study.	72
4.3	Comparison of Emotion Detection Rate between System.	79

LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	Mood Structure (Hume, 2008).	10
2.2	Speech Emotion Detection System (Shen <i>et al.</i> , 2011).	13
2.3	Summary of the effects of several emotion states on selected acoustic features (Shen <i>et al.</i> , 2011).	14
2.4	Example of FAC AUs (Lien <i>et al.</i> , 2000).	18
2.5	Example of perspective alignment (Lien <i>et al.</i> , 2000).	19
2.6	Samples of system testing. Words highlighted with green, blue and yellow shows respective emotions as labelled (Bao <i>et al.</i> , 2012).	23
2.7	Generic facial expression analysis framework (Fasel and Luetttin, 2003).	25
2.8	Consideration Aspect in Extraction Approaches.	27
2.9	3D modelling viewer with fitted mesh (Chang <i>et al.</i> , 2005).	28
2.10	Facial Characteristic Points (Pantic and Rothkrantz, 2000).	30
3.1	Overall Flowchart of The Study.	36
3.2	Pilot Study Experiment Set Up.	38
3.3	Summary of Video Description.	40
3.4	Pilot Study Experimental Procedure Flow Chart.	41
3.5	Facial expression while participant being induced by the negative emotion stimulus.	43
3.6	Facial expression while participant being induced by the positive emotion stimulus.	43

3.7	Facial expression of participant A, B, C and D while being induced with positive emotion video.	45
3.8	Facial expression changes from neutral to happy.	46
3.9	Algorithm Enhancement Block Diagram.	47
3.10	Integral Image Calculation.	48
3.11	The if else Matlab code for negative emotion rule (a). The shape formed based on the rule (b). Example of image that follows the rule (c).	51
3.12	The if else Matlab code for positive emotion rule (a). The shape formed based on the rule (b). Example of image that follow the rule (c).	52
3.13	Two points of centroid bounding box rule for negative emotion.	53
3.14	Two points of centroid bounding box rule for positive emotion.	54
3.15	Image Processing Flow Chart.	55
3.16	Algorithm Enhancement and Testing Stage.	57
3.17	Sample images of mimic facial expression, RD (a), D1(b) and D2(c).	58
3.18	a) ISED or D3 b) D4 and c) D5 images.	59
3.19	a) Experimental set up layout of D3 (Happy <i>et al.</i> , 2017). b) Experimental set up layout and software use in pilot study.	60
3.20	Experimental Procedure Flowchart.	61
3.21	Overview of images for database RD, D1, D2, D3, D4 and D5.	62
3.22	Overview Database Size.	65
4.1	Negative versus Positive Emotion Detection Percentage of Each Database.	70
4.2	Mimic versus Spontaneous Image Database Performance.	75
4.3	Comparison between Spontaneous and Mimic Expression.	76
4.4	Overall System Performance Analysis.	77

4.5	False Detection Percentage.	80
4.6	Mean Execution Time(s).	81
4.7	Emotion Detection Percentage of D5 Database.	84
4.8	Participant 1 of D5 expressing positive and negative emotion.	85
4.9	Number and Percentage of Correct Emotion Detection of Participants in D5.	85
4.10	Involuntary action in response to totally disgust feeling.	87
4.11	Sequence images of P1 while expressing negative emotion.	88
4.12	Snippet of negative emotion result from excel table.	89
5.1	Proposed Future Emotion Detection Interface.	93

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Overall Results.	104
B	Spontaneous versus Mimic Results.	105
C	D5 Results for Positive and Negative Emotion.	106
D	D5 Percentage Detection.	107

LIST OF ABBREVIATIONS

SED	-	Speech Emotion Detection
ASD	-	Automatic Speech Detection
FED	-	Facial Emotion Detection
RD	-	Reference Database
D1	-	Database 1
D2	-	Database 2
D3	-	Database 3
D4	-	Database 4
D5	-	Database 5
ISED	-	Indian Spontaneous Expression Database
HD	-	High Definition
AFA	-	Automatic Facial Analysis

LIST OF PUBLICATIONS

Journal

1. Monawir, R. P. H. R., Blar, N., Jafar, F. A., & Hasan, Z., 2016. Pilot Study of Emotion Recognition through Facial Expression. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, 8(2), pp. 17-21.
2. Monawir, R. P. H. R., Jafar, F. A., & Hasan, Z., 2017. The Preliminary Analysis of SSDXCORR Techniques Performance under Multivirtual Condition. *Asian Journal of Information*, 16(1).

Advance Science Letter (ASL)

1. Hazimah, R. P., Hasan, Z., & Jafar, F. A., 2017. A Comparison of SSDXCOR and CC Matching Techniques for Vision Inspection System. *Advanced Science Letters*, 23(6), pp. 5461-5465.

Conferences

1. System Configuration for Visual Emotion Recognition Through Android-Based Software, 4th International Conference On Advanced Manufacturing Technology 2015 Universiti Teknologi Mara (UTM) Skudai, Johor Bahru, Malaysia.
2. Preliminary Study Results of Emotion Recognition by Using Facial Expression and Brainwaves Signals, International Conference on Computer, Communication, and Control Technology 2016, Hotel Promenade, Sabah, 19th-21th April 2016

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Emotion is very crucial since it has great contribution to the human perception, decision making, as well as action execution and control (Surakka and Sams, 1999; Zhu and Thagard, 2002). In human-computer interaction, considering human emotion is important for creating affective interaction (Emerich, Lupu and Apatean, 2009). Note that, studies related to emotion are pioneer by Paul Ekman in 1982. Ekman suggest the six basic emotions and the relation of facial features with the emotion. In modern day, emotion could be detected via various analysis including visual, speech, physiological signals and combination analysis.

Visual analysis is one of the common methods to be used especially facial expression. Facial expression contributes most information while communicating with human (Sanchez-Mendoza, Masip and Lapedriza, 2015). Amongst the features that are used for emotion detection studies are lips (Huang and Fuh, 2007), eye pupil (Babiker *et al.*, 2015) and combination of several action units (Zhang *et al.*, 2013). Facial emotion detection could be implemented in many areas such as health monitoring (Lucey *et al.*, 2009), driving surveillance (Vural *et al.*, 2008), event detection (Ryan *et al.*, 2009), personalized learning (D'Mello and Graesser, 2010), and robotics (Zhang *et al.*, 2015). In medical field for example, facial expression emotion detection has been implemented in detecting the various

psychological problem including anxiety (Huang *et al.*, 2013) and depress (Meng *et al.*, 2013).

Beside visual analysis, speech analysis is another common method to detect emotion. Speech analysis involved acoustic and lexical aspects. While acoustic refer to the intonation, lexical referred to the selection of words to be used. Speech emotion detection system is widely been used in many applications for example, web movies, computer tutorial (Litman, Forbes and Silliman, 2003; Litman and Forbes-Riley, 2004) and in car board application.

Next is physiological signals or biological signals. This emotion detection utilized the used of human involuntary action such as body temperature (Quazi *et al.*, 2012), heartbeat (Valenza *et al.*, 2014) and breathing rate (Zhang *et al.*, 2017) to detect emotion. As compare to other methods, this method is more reliable since biological signals hard to be fabricated. Amongst the applications which utilized biological signals is driver stress detector (Chen *et al.*, 2017).

Realizing advance human computer intelligent has wide range of applications, a study related to human reaction and emotion under natural environment is done. This Human Spontaneous Emotion Detection System study focuses only on emotion detection via facial expression. A pattern detection is used to classify emotion into positive and negative emotion. It is a hope that in near future this detection system could be adapt into computer and robot.

1.2 Motivation

Adapting computer system or robot to be an ideal human companion as well as an assistant is the ulterior motive in human related interaction field. However, for these technologies to live together with the human, they need to perceive certain level of

intellectual. The capability of understanding emotion as well as respond appropriately and instantly are amongst the criteria for them to be sociable technologies. Therefore, motivated by these ideas, this project produces a system that has an instant emotion detection process. It is hope that this system could be implemented to the computer and finally the robot soon. When computers and robots have greater sensitivity to human feeling, the dream of having them as human ideal helpers could be realized soon.

1.3 Problem Statement

Nowadays, there has been emerging interest of enhancing every aspects of the human and computer interaction. It also been argued, is current computer system achieve effective human-computer intelligent interaction if the interaction cannot occur spontaneously like human-human interaction. Computer system does not have emotion or react to emotions. Moreover, current detection system studies and tested in controlled environment which is not represent real life situation. So it is a great challenge in so call computer intelligent system. (Sebe *et al.*, 2007).

In many applications of human–computer interaction, it is important to be able to detect the emotional state of the person in a natural situation. This is because emotion that is produce under controlled environment and mimic has subtle different than the spontaneous emotion (Sebe *et al.*, 2007). In terms of emotion detection via facial expression, pose and genuine emotions have slight differences in intensity and duration of facial movement (Ekman and Friesen, 2003). This happened since both emotions have different neural pathway results in slight differences in facial expression. However, despite of the need for authentic emotion which can represent spontaneous reaction in real life condition, most of the studies still used posed emotion such as (Cohen *et al.*, 2000; Mencattini *et al.*, 2014).

This happened since obtaining authentic spontaneous emotion requires significant effort in the selection of proper stimuli which can lead to rich display of intended emotions (Happy *et al.*, 2017). It is also time consuming (Wang *et al.*, 2010).

Even though experiment that is close to real life situation is considered as an ideal set up, the process of obtaining data would be challenging. It involved many unknown external parameters. According to Sebe *et al.* (2007), several aspects need to be considered for obtaining the genuine emotion which are method to induce, record, and testify the authenticity of the emotion. Moreover, emotion could not be expressed in rush, and some people would not act normally when they know they are being recorded. Besides, not all people expressed their feelings well and it may differ according to their life environment and experience. The processes and procedures of obtaining and developing genuine emotion database is challenging and difficult. Hence, because of these obstacles, most of the previous study used posed emotion rather than genuine emotion.

1.4 Research Question

Enhancing emotion detection algorithms and verification using spontaneous emotion lead to the questions as follows:

- i. What will be the algorithm that can detect spontaneous emotion in instant time?
- ii. How to induce, record, and verify the spontaneous emotion?
- iii. Is the spontaneous facial expression database and algorithm is applicable?

1.5 Hypothesis

Inducing and recording spontaneous emotion is possible depending on the method, subjects and environment that take place. Next, it is deduced that inducing the emotion of

someone that does not directly involved and has knowledge regarding this study will be helpful to create natural environment and respond.

Finally, it is predicted that negative emotion would be difficult since negative emotion normally require people to totally immerse in their feeling, before it can be seen through the expression.

1.6 Objectives

The main objective of this research is to enhance algorithms that can be implemented on a robot, so that the robot can recognize human emotion. However, to achieve the main objective, the following objectives need to be achieved first.

- a) To enhance an algorithm that can allow spontaneous emotion detection.
- b) To develop spontaneous facial expression database.
- c) To verify the performance of the emotion detection system in term of detection rate.

1.7 Scopes and Limitations

In order to provide clear boundaries for this study, the scopes and limitations of this study are set as follows:

- i. The emotions to be detected are labeled in general as positive and negative emotion. Studies have shown that the confusion normally happens while classifying almost similar emotion into detail emotion. For example, angry, hate and sadness or funny, happy and content. These emotions are hard to be differentiated and tend to be misinterpreted with one another. Therefore, to avoid confusion, this study classified emotion as two general groups, which are positive

and negative emotion. These two opposite emotions have distinct features and behavior from each other, thus easier to be differentiated. Moreover, recognizing emotion as positive and negative response is sufficient in the most applications, especially involving human robot interaction and education field.

- ii. The detection focuses only on facial areas, specifically lip features only. This is because lips show obvious muscle movement while displaying emotion. Moreover, narrowing facial area to be studied could shorten the execution time.
- iii. This study only focuses on 2D upright frontal images. Images that will be examined must have complete eyes, nose and mouth features. If one of the features is missing, image will be excluded from further verification. This is due to algorithm limitation that needs eyes, nose and mouth location in order to locate and extract features.
- iv. Developed algorithms for emotion detection will be done by using MATLAB.
- v. The experiment will be done in a normal environment where lighting is sufficient at room temperature. However, there is no certain value is set since the aim of the experiment is to have as near as real life surrounding as possible. Any images that do not have sufficient lighting will be excluded from further verification.
- vi. The distance between camera and participants are set under 1m (only for own spontaneous database setup).
- vii. All participants are assumed does not have occlusion and accessories such as spectacles are ignored.
- viii. Amateur decoder is sufficient for this experiment since it only involves general emotion classification.
- ix. This study is carried out for studying Malaysian spontaneous facial expression. It is assumed the Malaysian multicultural have same display rule emotion.

However, for testing purpose, the databases used may include other than Malaysian images.

1.8 Thesis Outline

This thesis is structured as follows:

Chapter 1 starts with the general ideas of emotion detection in the introduction. Next, in the problem statement, research objectives and scope of the research, basic foundation of this study is stated. Finally, the general overview of every chapter is explained in the outline section.

Chapter 2 is a chapter that review associated studies of emotion detection, innovations and technologies. In this chapter, brief discussion and comparison are done in term of techniques, algorithms, technologies and methodologies used. This chapter is vital for guiding, supporting and arguing the flow of work for this study.

Chapter 3 evolves around the methodology that we used for this study. Hardware, software, algorithms and experiment details are amongst the main issues that being discussed in detail.

Chapter 4 of this thesis explains the results and analysis that has been done for this study. The analysis in numerical data aids in determining the system feasibility and effectiveness to achieve its target.

Chapter 5 states the conclusion of the research, research contribution and recommends future works in this area.