



**UNIVERSITI PUTRA MALAYSIA**

**MODELLING OF HEAD MOVEMENT IN  
EXPRESSION OF DISGUST**

**FAKHRUL HAZMAN YUSOFF**

**FSKTM 2010 9**



**MODELLING OF HEAD MOVEMENT IN  
EXPRESSION OF DISGUST**

**FAKHRUL HAZMAN YUSOFF**

**DOCTOR OF PHILOSOPHY  
UNIVERSITI PUTRA MALAYSIA**

**2010**



**MODELLING OF HEAD MOVEMENT IN EXPRESSION OF DISGUST**

**By**

**FAKHRUL HAZMAN YUSOFF**

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

**October 2010**



## **DEDICATION**

*To my parents, families and friends.*



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

**MODELLING OF HEAD MOVEMENT IN EXPRESSION OF DISGUST**

By

**FAKHRUL HAZMAN YUSOFF**

**October 2010**

**Chairman : Associate Professor Rahmita Wirza O.K. Rahmat, PhD**

**Faculty : Computer Science and Information Technology**

Head movement modelling can be seen as a part of facial expression study because some expressions like disgust involves head movement. Head movement information can be acquired by video recording process. The recording process has to deal with image distortion correctable via plumb-line method. Unfortunately the linear fitting used in plumb-line requires piecewise function. The thesis aims to enhance the plumb-line-based image distortion correction using conic function coefficient evaluation replacing linear fitting. Experiments conducted shows that the proposed method handles various line orientations without having to rely on piecewise function.

Besides distortion correction, an approach for expression movement tracking is needed. Optical flow-template matching is one of the techniques used for tracking. However, existing search algorithms did not discuss much on the looping technique of template matching. Moreover, tracking transient features during expression requires special process as the feature exists intermittently. The thesis aims to enhance the optical flow-template matching-based tracking method for tracking feature points during head movement by controlling the search loop and introducing



anchoring to handle transient components. Experiment showed that the proposed method recorded a reduction in comparison of 40.1% over another similar method during worse case scenario. Besides reduction, the proposed method also lowered the lost point during searching when compared with existing method.

Head movement modelling is not given proper attention in facial expression study hence affecting head model believability in computer graphics. The thesis aims to design head movement quantification method for head movement during disgust expression. The quantification method tracks movements of the head inclusive of the neck and named as ‘Dual Pivot Head Tracking’ (DPHT). To prove that it is perceptually better to use the proposed method, a perceptual study of expression with and without head movement was conducted. Results showed that subjects perceived disgust expression better if the proposed method is used ( $\chi^2$ -score of neck given head=14.9 vs. head given neck=3.59). To further support our proposal on the need to track head movement inclusive of the neck, experiments tracking subjects depicting disgust were conducted. A statistical two-tailed test to evaluate the existence of neck motion during head movement was done. Furthermore, visual comparison was made with a model without head movement approach. Results showed that neck motion was presence during head movement of disgust ( $z$ -score = 3.4 with  $p$ -value = 0.0006). Similarly the visual depictions showed that without the head movement inclusive of neck the rendering seemed to be incomplete.

Having movement information, the thesis aims to design a temporal model of head movement during disgust expression. Neck motion, a part of head motion, plays a role during disgust expression. The thesis proposes spline-based function named

Joint Cubic Bezier (JCB) to model neck motion during disgust. Experiments showed that using JCB, analysis and synthesis of neck motion during disgust expression is better than via cosine and exponential approach with angular separation score of JCB=0.986041, Exponential=0.897163 and Cosine=0.90773.

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

## **PEMODELAN PERGERAKAN KEPALA SEMASA EKSPRESI JIJK**

Oleh

**FAKHRUL HAZMAN YUSOFF**

**Oktober 2010**

**Pengerusi : Professor Madya Rahmita Wirza O.K. Rahmat, PhD**

**Fakulti : Sains Komputer dan Teknologi Maklumat**

Pemodelan pergerakan kepala harus dilihat sebagai sebahagian daripada kajian ekspresi muka kerana sesetengah ekspresi seperti ekspresi jijik melibatkan pergerakan kepala. Maklumat pergerakan kepala boleh diperolehi dengan membuat rakaman video pergerakan kepala. Proses rakaman perlu menangani isu herotan gambar yang boleh ditangani dengan menggunakan kaedah '*plumb-line*'. Malangnya penggunaan pepadanan linear di dalam '*plumb-line*' bermakna fungsi berdasarkan bahagian (*piecewise*) terpaksa digunakan. Sasaran tesis ini ialah untuk menambah baik pembetulan herotan kaedah '*plumb-line*' melalui cara menggantikan pendekatan pepadanan linear dengan penggunaan penilaian pekali untuk fungsi berasaskan kon. Ujikaji yang dijalankan menunjukkan penggunaan pendekatan yang dicadangkan membolehkan pengesanan garis herot dapat dijalankan tanpa bergantung kepada fungsi berdasarkan bahagian.

Di samping pembetulan herotan, pendekatan untuk penjejakan ekspresi perlu dilakukan. Gabungan kaedah aliran berasaskan optik (*optical flow*) dan pepadanan berdasarkan pencontoh (*template matching*) adalah satu cara untuk jejukan.





Walaupun bagaimanapun, algoritma gelintar sedia ada tidak membicarakan secara terperinci tentang teknik gelungan untuk pepadanan berdasarkan pencontoh. Tambahan pula, jejak objek boleh-ubah semasa ekspresi memerlukan pendekatan khusus untuk menangani bahagian yang berubah-ubah ini. Tesis ini mensasarkan untuk menambah baik jejak kaedah aliran berasaskan optik-pepadanan berdasarkan pencontoh (*optical flow-template matching*) untuk menjejaki pergerakan kepala dengan mengawal gelungan gelintar dan menambat gelintar kepada komponen muka yang pegun bagi menangani isu perubahan muka semasa ekspresi. Eksperimen yang dijalankan menunjukkan dengan menggunakan kaedah yang dicadang perbandingan semasa gelintar dapat dikurangkan sehingga 40.1% dan kes kehilangan jejak adalah lebih sedikit berbanding dengan kaedah sedia ada.

Pemodelan pergerakan kepala tidak diberikan perhatian yang sempurna di dalam kajian ekspresi menyebabkan kadar kebolehppercayaan model kepala di dalam grafik perkomputeran akan terjejas. Tesis ini memperkenalkan satu kaedah pengukuran pergerakan kepala semasa pergerakan kepala akibat jujuk dan dinamakan sebagai 'Kaedah Jejak berasaskan Dwi Pivot' (DPHT). Untuk membuktikan bahawa secara persepsinya kaedah dicadang adalah lebih baik, satu kajian persepsi telah dijalankan membandingkan pergerakan dengan dan tanpa kepala. Hasil telah menunjukkan bahawa manifestasi ekspresi oleh kepala termasuk leher adalah lebih berpengaruh ketika ekspresi jujuk (*skor  $\chi^2$*  leher diberi kepala =14.9 dan kepala diberi leher = 3.59). Sebagai sokongan tambahan untuk cadangan kami di dalam keperluan untuk menjejaki kepala termasuk leher, eksperimen menjejaki subjek berekspresi jujuk telah dijalankan. Satu analisa statistik ujian dwi-ekor dijalankan untuk menunjukkan kewujudan pergerakan leher semasa pergerakan kepala. Di samping itu bandingan

berdasarkan paparan visual akan dibuat membandingkan kaedah dicadang dan kaedah pergerakan tanpa pergerakan kepala. Hasil eksperimen menunjukkan adanya pergerakan leher semasa pergerakan kepala akibat ekspresi jijik ( $skor-z = 3.4$  dan  $nilai-p = 0.0006$ ). Paparan visual juga menunjukkan bahawa tanpa bahagian leher, paparan kelihatan tidak sempurna.

Setelah mendapatkan maklumat pergerakan kepala, sasaran tesis ialah mereka model temporal pergerakan kepala semasa ekspresi jijik. Pergerakan leher memainkan peranan yang penting di dalam pergerakan kepala semasa ekspresi jijik. Tesis ini mencadangkan model berasaskan '*spline*' dan dinamakan 'Gabungan Bezier Berasaskan Kiub' (JCB) untuk pergerakan leher semasa ekspresi jijik. Eksperimen menunjukkan penggunaan kaedah dicadang untuk analisa dan sintesis pergerakan leher semasa ekspresi jijik adalah lebih baik dibanding fungsi berasaskan kosinus dan eksponen dengan skor sudut pisahan JCB=0.986041, Exponential=0.897163 dan Cosine=0.90773.

## ACKNOWLEDGEMENTS

I would like to thank my supervisor, Associate Professor Dr. Rahmita (Universiti Putra Malaysia, Malaysia), the co-supervisors, Professor Dr. Mohamed Hatta Shaharom (Cyberjaya University College of Medical Sciences, Malaysia), Associate Professor Dr. Mohd Nasir Sulaiman (Universiti Putra Malaysia, Malaysia) and Dr. Hariyati Shahrina Shahrina Abdul Majid (International Islamic University, Malaysia) for their guidance and advises to make this thesis possible.



I certify that an Examination Committee has met on **13 October 2010** to conduct the final examination of **Fakhrul Hazman Yusoff** on his **Doctor of Philosophy** thesis entitled "**Modelling of Head Movement in Expression of Disgust**" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Examination Committee were as follows:

**Abdul Azim Abdul Ghani, PhD**

Professor

Faculty of Computer Science and Information Technology

Universiti Putra Malaysia

(Chairman)

**Lili Nurliyana Abdullah, PhD**

Faculty of Computer Science and Information Technology

Universiti Putra Malaysia

(Internal Examiner)

**Sudhir Pandurang Mudur, PhD**

Professor

Department of Computer Science & Software Engineering

Concordia University, Canada

(External Examiner)

**Abdul Razak Hamdan, PhD**

Professor

Fakulti Teknologi & Sains Maklumat

Universiti Kebangsaan Malaysia

(External Examiner)

---

**SHAMSUDDIN SULAIMAN, PhD**

Professor and Deputy Dean

School of Graduate Studies

Universiti Putra Malaysia

Date: 18 January 2011

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:

**Rahmita Wirza O.K. Rahmat, PhD**

Associate Professor  
Faculty of Computer Science and Information Technology  
Universiti Putra Malaysia  
(Member)

**Mohamed Hatta Shaharom, MBBCh, Mmed(Psych)**

Professor  
Faculty of Medicine  
Cyberjaya University College of Medical Sciences  
(Member)

**Mohd Nasir Sulaiman, PhD**

Associate Professor  
Faculty of Computer Science and Information Technology  
Universiti Putra Malaysia  
(Member)

**Hariyati Shahrina Abdul Majid, PhD**

Assistant Professor  
Kulliyah of Islamic Revealed Knowledge & Human Sciences  
International Islamic University Malaysia  
(Member)

---

**HASANAH MOHD GHAZALI, PhD**

Professor and Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date:



## **DECLARATION**

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

---

**(FAKHRUL HAZMAN YUSOFF)**

Date: 13 October 2010

## TABLE OF CONTENTS

		<b>Page</b>
<b>DEDICATION</b>		ii
<b>ABSTRACT</b>		iii
<b>ABSTRAK</b>		vi
<b>ACKNOWLEDGEMENTS</b>		ix
<b>APPROVAL</b>		x
<b>DECLARATION</b>		xii
<b>LIST OF TABLES</b>		xvii
<b>LIST OF FIGURES</b>		xix
<b>LIST OF APPENDICES</b>		xxiii
<b>LIST OF ABBREVIATIONS</b>		xxiv
<b>CHAPTER</b>		
<b>1</b>	<b>INTRODUCTION</b>	<b>1</b>
	1.1. Introduction	1
	1.2. Research Problem	2
	1.3. Thesis Objectives	5
	1.4. Thesis Scope	5
	1.5. Thesis Structure	7
	1.6. Research Methodology	8
	1.7. Research Design	9
<b>2</b>	<b>BACKGROUND</b>	<b>11</b>
	2.1. Introduction	11
	2.2. Image Distortion Problem	16
	2.3. Face Tracking Using A Combination of Optical Flow and Template Matching	20
	2.4. Emotion and Expression	23
	2.5. Head Movement and Facial Expression	26
	2.6. Head Movement Quantification	30
	2.7. Temporal Modelling of the Neck	31
	2.8. Conclusions	34
<b>3</b>	<b>LITERATURE REVIEW</b>	<b>36</b>
	3.1. Expression Elicitation Technique	36
	3.2. Establishing the Straightness of a Line for Radial Distortion Correction through Conic Fitting	40
	3.3. Tracking Facial Expression using Template Matching and Optical Flow	43
	3.4. Head Movement Quantification and Modelling	51
	3.5. Temporal Modelling of the Neck Movement during Head Pulling in the context of Disgust Expression	60
	3.6. Conclusion	64



4	<b>PROPOSED METHOD</b>	67
4.1.	Establishing Straightness of a Line for Radial Distortion Correction through Conic Fitting	68
4.2.	Optical flow based, Normalized Cross Correlation, Flexible Rectangular Search (RtS-Opf-Flex-NCC)	72
4.2.1.	Complex Numbers and Rectangular Search	73
4.2.2.	Optical Flow Analysis as Motion Predictor	81
4.2.3.	Similarity Comparison in Template Matching Using Anchoring Normalized Cross Correlation Approach	85
4.3.	Dual Pivot Head Tracking System for Incorporation in Facial Expression Modelling	87
4.3.1.	2D DPHT	88
4.3.2.	3D Extension	95
4.4.	Temporal Modelling of Head Pulling during Disgust Expression via Joint Cubic Bezier Modelling approach	99
4.4.1.	Establishing General Head Movement During Head Pulling	99
4.4.2.	Joint Cubic Bezier Fitting	101
4.5.	Conclusion	104
5	<b>EXPERIMENTS</b>	105
5.1.	Sampling	105
5.2.	Experiments Conducted	108
5.3.	Experiments on Radial Distortion Correction using Conic Fitting	109
5.3.1.	Experiment 1	110
5.3.2.	Experiment 2	113
5.4.	Experiments on Tracking Technique with RtS-Opf-Flex-NCC	113
5.4.1.	Experiment 1 - Comparing RtS-Opf-Flex-NCC with Existing Template Matching-Optical Flow Technique	114
5.4.2.	Experiment 2 - Tracking State Changing and Transient Areas Using Anchoring Methods	117
5.5.	Perception Study on the role played by the Neck and Skull during Facial Expression of Disgust	117
5.6.	Head Movement Quantification	124
5.6.1.	DPHT Statistical Evaluation - Experiment 1	125
5.6.2.	DPHT Visual Inspection - Experiment 2	128
5.7.	Experiments on Temporal Modelling of Head Pulling During Disgust Expression via Joint Cubic Bezier Modelling approach	129
5.7.1.	Similarity Test between motion produced by JCB and human subject - Experiment 1	130
5.7.2.	Similarity Test between motion produced by JCB and multiple human subjects - Experiment 2	135
5.8.	Conclusion	136



6	<b>RESULTS &amp; DISCUSSION</b>	138
	6.1. Results of Experiments on Radial Distortion Correction using Conic Fitting	138
	6.2. Discussion of Experiments on Radial Distortion Correction using Conic Fitting	154
	6.3. Results of Experiments on Tracking Technique with RtS-Opf-Flex-NCC	155
	6.3.1. Experiment 1 - Results on Comparing RtS-Opf-Flex-NCC with Existing Template Matching-Optical Flow Technique	155
	6.3.2. Experiment 2 - Results on Tracking State Changing and Transient Areas Using Anchoring Methods	158
	6.4. Discussion of Experiments on Tracking Technique with RtS-Opf-Flex-NCC	159
	6.5. Results of Perception Study on the role played by the Neck and Skull during Facial Expression of Disgust	162
	6.6. Discussion of Perception Study on the role played by the Neck and Skull during Facial Expression of Disgust	168
	6.7. Head Movement Quantification	169
	6.7.1. Results on DPHT Statistical Evaluation - Experiment 1	169
	6.7.2. Results on DPHT Visual Inspection - Experiment 2	171
	6.8. Discussion of Head Movement Quantification	173
	6.9. Results of Experiments on Temporal Modelling of Head Pulling via Joint Cubic Bezier Modelling approach	176
	6.9.1. Results on Similarity Test between motion produced by JCB and human subject - Experiment 1	176
	6.9.2. Results on Similarity Test between motion produced by JCB and multiple human subjects - Experiment 2	177
	6.10. Discussion of Experiments on Temporal Modelling of Head Pulling via Joint Cubic Bezier Modelling approach	180
	6.11. Conclusion	181
7	<b>CONCLUSION &amp; FUTURE WORKS</b>	182
	7.1. Expression Elicitation and Facial Expression	182
	7.2. Image Distortion Correction	183
	7.3. Head Tracking	184
	7.4. Head Movement Quantification with Dual Pivot Head Tracking System	186
	7.5. Temporal Model with Joint Cubic Bezier	187
	7.6. Summary	189

<b>REFERENCES</b>	191
<b>BIODATA OF STUDENT</b>	221
<b>LIST OF PUBLICATIONS</b>	222

