UNIVERSITI PUTRA MALAYSIA

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DOCTOR OF PHILOSOPHY

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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 (χ^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 JIJIK

Oleh

FAKHRUL HAZMAN YUSOFF

Oktober 2010

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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 rakamkan video pergerakan kepala. Proses rakaman perlu menangani isu herotan gambar yang boleh ditangani dengan menggunakan kaedah '*plumb-line*'. Malangnya penggunaan pemadanan 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 pemadanan 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 pemadanan berdasarkan pencontoh (*template matching*) adalah satu cara untuk jejakan.

Walaubagaimanapun, algoritma gelintar sedia ada tidak membicarakan secara terperinci tentang teknik gelungan untuk pemadanan berdasarkan pencontoh. Tambahan pula, jejakan objek boleh-ubah semasa ekspresi memerlukan pendekatan khusus untuk menangani bahagian yang berubah-ubah ini. Tesis ini mensasarkan untuk menambah baik jejakan kaedah aliran berasaskan optik-pemadanan 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 kebolehpercayaan model kepala di dalam grafik perkomputeran akan terjejas. Tesis ini memperkenalkan satu kaedah pengukuran pergerakan kepala semasa pergerakan kepala akibat jijik dan dinamakan sebagai 'Kaedah Jejakan 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 jijik (*skor* χ^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 menjejak subjek berekspresi jijik telah dijalankan. Satu analisa statistik ujian dwi-ekor dijalankan untuk menunjukkan kewujudan pergerakan leher semasa pergerakan kepala. Di samping itu bandingan

berasaskan 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.

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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.

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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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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.

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(FAKHRUL HAZMAN YUSOFF)

Date: 13 October 2010

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