

Real-Time Hand Gesture Recognition using Motion Tracking

By

ZHU HONGMIN

Master Degree of Software Engineering

2010



Faculty of Science and Technology
University of Macau

Real-Time Hand Gesture Recognition using Motion Tracking



Approved by _____

Supervisor

Date _____

In presenting this thesis in partial fulfillment of the requirements for a Master's degree at the University of Macau, I agree that the Library and the Faculty of Science and Technology shall make its copies freely available for inspection. However, reproduction of this thesis for any purposes or by any means shall not be allowed without my written permission. Authorization is sought by contacting the author at

Address: JLG216, Silver Jubilee Building, University of Macau, Macau SAR, China

Telephone: (+853)66648357

Fax:

E-mail: zhu.herman@gmail.com



Signature _____

Date _____

University of Macau

Abstract

Real-Time Hand Gesture Recognition using Motion Tracking

by ZHU HONGMIN

Thesis Supervisor: Associate Professor Pun ChiMan

Master Degree Program of Software Engineering

This paper introduces an attractive alternative human computer interaction interface in future applications, which is the gesture performed by the user. Especially we focus on hand gestures by using its motion representation and several techniques and related works in recent years are reviewed. A gesture recognition system of 10 hand signed digits is proposed in our research, in which we firstly compared different solutions of detecting active hand in a video frame and concluded our skin-subtraction approach, and then locations of hand in a sequence of frames are tracked to extract the feature of motion track. Finally we used the histogram distribution models to recognize each location track as one of ten digits. Our proposed system achieves a recognition rate of 97.33% and also supports for the real-time application.

TABLE OF CONTENTS

LIST OF FIGURES	iii
LIST OF TABLES	v
LIST OF ABBREVIATIONS.....	vi
PREFACE	vii
Chapter 1 Introduction	1
1.1 Human Computer Interaction	1
1.2 Challenges in Hand Gesture Recognition.....	3
1.3 Outline of Contents	5
Chapter 2 Review of Hand Gesture Recognition Approaches.....	7
2.1 Hand and Gesture Modeling	7
2.2 Hand Gesture Analysis	10
2.2.1 Feature Detection.....	11
2.2.2 Parameter Estimation.....	12
2.3 Hand Gesture Recognition.....	13
2.3.1 HMMs for Hand Gesture Recognition.....	13
2.3.2 Particle Filtering and Condensation Algorithm.....	16
2.3.3 FSMs for Hand Gesture Recognition.....	18
2.3.4 Soft Computing and Connectionist Approach.....	19
Chapter 3 Design of Hand Gesture Recognition System.....	21
3.1 System Architecture.....	21
3.2 Hand Detection in Single Frame.....	24
3.2.1 Review of Color Spaces.....	25
3.2.2 Skin Color based Hand Detection.....	28
3.2.3 Inter-frame Difference based Hand Detection.....	31
3.2.4 Skin-subtraction Hand Detection.....	31
3.3 Motion Tracking	32
3.4 Classification of Hand Gesture Track.....	34
3.4.1 Track Normalization and Encoding.....	35
3.4.2 Recognition using HMMs.....	39
3.4.3 Recognition using Histogram Distribution.....	40
Chapter 4 Experimental Results and Discussion	44
4.1 Results of Hand Detection	44

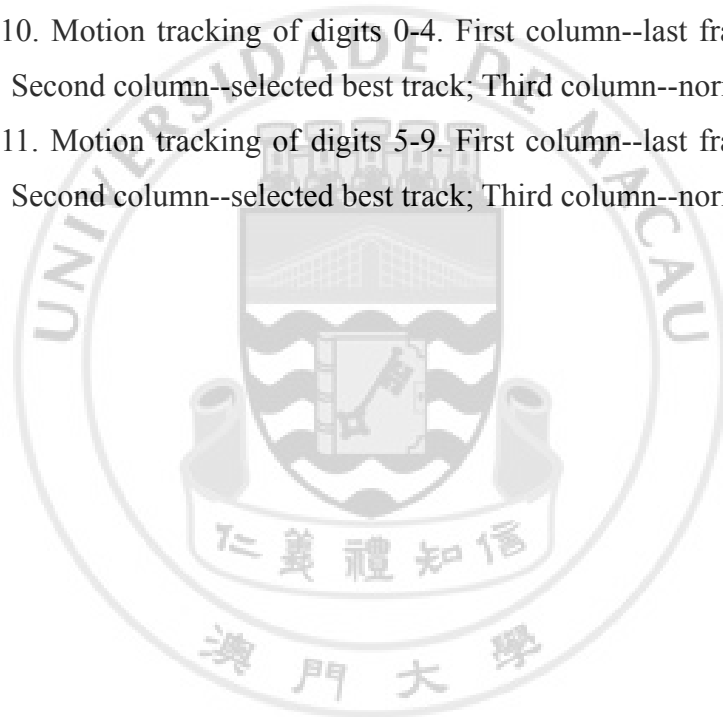
4.1.1 Approach on Skin-color Classification	44
4.1.2 Approach on Skin-subtraction	47
4.2 Results of Motion Tracking	50
4.3 Results of Gesture Recognition	54
4.3.1 HMMs Recognition	55
4.3.2 Histogram Recognition	55
Chapter 5 Conclusion and Future Work	58
References.....	60



LIST OF FIGURES

<i>Number</i>	<i>Page</i>
Figure 1- 1. A taxonomy of hand gestures for HCI.....	1
Figure 2- 1. Skeletal hand model: (a) Hand anatomy, (b) the kinematic model.....	9
Figure 2- 2. Analysis and recognition of gestures.....	11
Figure 2- 3. Five-state left-to-right HMM for gesture recognition.....	15
Figure 3- 1. System flowchart. Dashed lines indicate flow during offline learning. Solid lines indicate flow during online recognition.....	22
Figure 3- 2. Palm’s Graffiti Digits.....	22
Figure 3- 3. framework of proposed system.....	23
Figure 3- 4. Workflow of gesture tracking.....	24
Figure 3- 5. RGB color space.....	26
Figure 3- 6. HSL (a–d) and HSV (e–f).....	27
Figure 3- 7. Erosion and dilation.....	30
Figure 3- 8. Workflow of gesture recognition.....	35
Figure 3- 9. Normalization of digit track “6”.....	38
Figure 3- 10. Categories of vector directions.....	39
Figure 3- 11. histograms of 10 digits.....	42
Figure 4- 1. Result of skin detection in RGB color space: a) original frame. b) Skin pixels. c) De-noise and region connection. d) Region splitting. e) Region centers.....	45
Figure 4- 2. Effect of lighting condition on the skin detection in RGB color space: a) Original frame. b) Skin pixels.....	45
Figure 4- 3. Result of skin detection in HSV color space: a) Original frame. b) Skin pixels. c) De-noise and region connection.....	46
Figure 4- 4. Result of skin detection in YCbCr color space: a) original frame. b) Skin pixels. c) De-noise and region connection. d) Region splitting. e) Region centers.....	46
Figure 4- 5. Effect of lighting condition on the skin detection in YCbCr color space: a) Original frame. b) Skin pixels.....	47
Figure 4- 6. Result of hand detection using inter-frame difference: a) 1st frame. b)	

20 th frame. c) Subtraction of (a) and (b). d)threshold of (c). e) De-noise. g) Region centers.	48
Figure 4- 7. proposed hand detection of skin-subtraction : a) background frame. b) Skin in background. c) 20 th frame. d) Skin in 20 th frame. e) Exclusive-or of (b) and (d). f) AND (e, NOT (b)). g) De-noise. h) Region center.....	50
Figure 4- 8. Problem of skin-colored cloth: a) background frame. b) Skin in background. c) 19 th frame. d) Skin in 19 th frame. e) Exclusive-or of (b) and (d). f) AND (e, NOT (b)). g) De-noise. h) Region center.	50
Figure 4- 9. Motion tracking on standard dataset. First column: last frame of gesture; Second column: selected best track; Third column: normalized track.	52
Figure 4- 10. Motion tracking of digits 0-4. First column--last frame of gesture; Second column--selected best track; Third column--normalized track.	53
Figure 4- 11. Motion tracking of digits 5-9. First column--last frame of gesture; Second column--selected best track; Third column--normalized track.	54



LIST OF TABLES

<i>Number</i>	<i>Page</i>
Table 2- 1. static and dynamic constrains on finger joint angle.....	10
Table 3- 1. Skin color ranges	28
Table 3- 2. Chain code calculation.....	39
Table 3- 3. histogram models for 10 digits	43
Table 4- 1. HMMs Recognition rate on standard dataset.....	55
Table 4- 2. Recognition rate in segment/non-segment models	57
Table 4- 3. Count of incorrect classification by non-segment model	57



LIST OF ABBREVIATIONS

HCI--Human Computer Interaction
VE--Virtual Environment
CV--Computer Vision
DOF--Degree of Freedom
MCP--Metacarpophalangeal
IP--Interphalangeal
CMC--Carpometacarpal
TM--Trapeziometacarpal
MHI--Motion History Image
PCA--Principle Component Analysis
HMMs--Hidden Markov Models
KF--Kalman Filtering
FSM--Finite State Machine
MLP--Multilayer Perceptron
TDNN--Time Delay Neural Network
RBFN--Radial Basis Function Network
ANN--Artificial Neural Network
GA--Genetic Algorithm
ASL--American Sign Language
CIE--International Commission on Illumination

PREFACE

In this paper we introduce an attractive research topic on a new generation of human computer interface in modern computer vision systems, which use the hand gesture to interact with environment directly. The background of hand gesture recognition as well as its widespread applications is introduced. Also we discussed some problems and difficulties for the design of a robust and reliable gesture recognition system. Some of proposed works are viewed for each of three stages involved in hand gesture recognition system: gesture modeling, gesture analysis and gesture recognition.

As color cues based and motion cues based solutions are most commonly used for detect object in video frames, we gave a comparison of hand detection in different color spaces and the YCbCr is experimented to be more reliable. Further more, we motivate from the motion cues approach to take inter-frame correlation into consideration and incorporate a modified background subtraction process with skin-color based hand detection in YCbCr space. The best motion track is extracted from multiple track candidates based on their stand derivation measurement. Each track of gesture digit is normalized and smoothed, and encoded into chain code for training models of each gesture class. Compared with Hidden Markov Models (HMMs) tool, we proposed a simple model on the histogram distribution which is shown to be reliable for gesture classification. We achieve a recognition rate of 97.33% out of 300 digit gestures and the computational efficiency is around 60 fps which can support the requirement of real time applications.

ACKNOWLEDGMENTS

The author wishes to thank his supervisor Pun ChiMan (associate professor, University of Macau) who was abundantly helpful and offered invaluable assistance, discussion, support and guidance during each phase in accomplishing this thesis work.

The author would also like thank members in his laboratory, his classmates and friends for their support and advises which are indispensable to the success of his algorithm implementation and final paper writing. Especially they helped to provide camera videos of gesturing which are used as a dataset for testing the proposed system.

Finally the author thanks members from the examination committee for their reviewing work of his thesis report.

