Current Natural Sciences

COMPUTER VISION & ARTIFICIAL INTELLIGENCE

Bin SONG and Zhiyong ZHANG

Facial Expression Recognition Technology for Human-Computer Interaction

SCIENCE PRESS

edp sciences

Current Natural Sciences



Facial Expression Recognition Technology for Human-Computer Interaction

Bin SONG and Zhiyong ZHANG

This book provides a systematic study of facial expression recognition technology for human-computer interaction, covering the complete processing pipeline from image preprocessing to expression classification. The research presented in this book, supported by the National Natural Science Foundation of China, offers a comprehensive framework for facial expression recognition, including a fractional-step color constancy algorithm for complex illumination conditions, multi-feature fusion strategies, and theoretical innovations with practical engineering applications.

This book will be a valuable reference for graduate students and advanced undergraduates studying computer vision and related subjects, as well as for researchers and engineers working in artificial intelligence, computer vision, affective computing, and human-computer interaction.

Bin SONG is an Associate Professor and a graduate supervisor of Information Engineering College (Artificial Intelligence College) at Henan University of Science and Technology, China. He received his Ph.D. degrees in Computer Science and Engineering from Korea University, South Korea. His research interests include artificial intelligence, computer vision, affective computing, and cyberspace security.

Zhiyong ZHANG is Director of Information Engineering College (Artificial Intelligence College), Director of Institute of Artificial Intelligence Innovations, and full-time Henan Province Distinguished Professor at Henan University of Science and Technology, China. He received his Ph.D. degrees in Computer Science from Xidian University, China. His research interests include cyberspace security and privacy computing, artificial intelligence and multimodal large language model, industrial cyber-physical system and industrial internet security.

ISBN : 978-2-7598-4103-5

9 782759 841035

edp sciences
www.edpsciences.org

SCIENCE PRESS

Current Natural Sciences

Bin SONG and Zhiyong ZHANG

Facial Expression Recognition Technology for Human-Computer Interaction

SCIENCE PRESS

edp sciences

The contents of this book were originally published by Science Press in 2022 and are reproduced herein with the permission of and in collaboration with Science Press.

Printed in France

EDP Sciences – ISBN(print): 978-2-7598-4103-5 – ISBN(ebook): 978-2-7598-4104-2
DOI: 10.1051/978-2-7598-4103-5

All rights relative to translation, adaptation and reproduction by any means whatsoever are reserved, worldwide. In accordance with the terms of paragraphs 2 and 3 of Article 41 of the French Act dated March 11, 1957, "copies or reproductions reserved strictly for private use and not intended for collective use" and, on the other hand, analyses and short quotations for example or illustrative purposes, are allowed. Otherwise, "any representation or reproduction – whether in full or in part – without the consent of the author or of his successors or assigns, is unlawful" (Article 40, paragraph 1). Any representation or reproduction, by any means whatsoever, will therefore be deemed an infringement of copyright punishable under Articles 425 and following of the French Penal Code.

This book cannot be reproduced or used for training artificial intelligence systems. Text and data mining is prohibited in accordance with Article 4(3) of Directive (EU) 2019/790.

The printed edition is not for sale in Chinese mainland. Customers in Chinese mainland please order the print book from Science Press. ISBN of the China edition: Science Press 978-7-03-067466-1

© Science Press, EDP Sciences, 2026

Preface

The acquisition and analysis of facial expression information is the key to achieve natural communication in human computer interaction. Therefore, research on facial expression recognition has attracted considerable attention in recent years. Facial expression recognition, as an interdisciplinary research field of artificial intelligence, computer vision, image processing, psychology, cognition and so on, can realize intelligent and more natural human-computer interaction environment, which has great application value. Generally speaking, the process of facial expression recognition includes image preprocessing, face detection, facial feature location, expression feature extraction, and expression classification. Based on the existing research achievement, this book makes an in-depth study on the key issues of facial expression recognition in human-computer interaction. The main research contents are as follows:

（1）Research on the constancy of color images. According to the principle of modularity in visual information processing, a fractional-step color constancy method for color images under complex illumination conditions is proposed. This method overcomes the ill-posed problem of traditional color constancy, and can maintain the color constancy of images under complex illumination, such as partial color and low illumination, and effectively improve the contrast and brightness of images.

（2）Research on face detection. Face detection is the preliminary work and basis of facial expressions recognition. A face detection method based on multi-feature fusion is proposed. This method enables multiple features to cooperate with each other for efficient and accurate face detection.

（3）Research on facial feature location. The accurate positioning of the facial features is the key to correct recognition. For grayscale images, an eye location method based on multi-scale self-quotient graph and morphological

filtering is proposed. For color images, a face key feature location method based on face color information features is proposed. These methods have high accuracy rate, and they are robust for the variation of the expressions and poses.

(4) Research on facial expression image normalization. The geometrical characteristics and optical properties of facial expression image should be normalized before expression feature extraction. The pure expression image after normalization has uniform size, angle, and luminance, and removes the impact of the light and intensity of illumination.

(5) Research on expression feature extraction and expression classification. A facial expression recognition method based on supervised orthogonal locality preserving projection is proposed. According to the characteristics of facial expressions, this method firstly combines Gabor local statistical features with LBP (local binary patterns) texture features as composite expression features, and then reduces the feature dimension by applying supervised orthogonal locality preserving projection. Finally, facial expressions can be classified by adopting nearest neighbor algorithm. The proposed method makes use of category prior knowledge to further improve classification performance.

At last, this book summarizes the innovation points and main research results, and points out the problems of further research.

In recent years, the authors have been engaged in the research work in computer vision, image processing, pattern recognition and other fields. Combining the new achievements, new developments and trends in the field of facial expression recognition, it is necessary to write an academic work, in which the related theories and methods are systematically introduced. It is expected that the publication of this book can play a certain role in promoting the research and application in this field.

The book consists of 8 chapters, among of which Chapter 2-7 written by Song Bin from Henan University of Science and Technology, and Chapter 1 and Chapter 8 written by Zhang Zhiyong from Henan University of Science

and Technology. The Publication of this book was sponsored by National Natural Science Foundation of China (Grant No.61972133 and No.12101195), Henan Province Natural Science Fund (Grant No.202300410146), Henan Province Key Scientific and Technological Projects (Grant No.222102210177, No.222102210072, No.212102210383, and No.202102210162).

During the writing process of the book, the authors refer to the books, the application results and advanced technologies of domestic and foreign counterparts. The authors are very grateful. Restricted by limited level of the writers, it is unavoidable that there are mistakes in the book. The authors urge all experts, scholars, and readers to give advice for correction.

Authors

March, 2022

Contents

Preface

Chapter 1 Introduction ····· 1

1.1 Research Background and Significance ····· 1

1.2 Overview of Facial Expression Recognition ····· 4

1.3 Research Status at Home and Abroad ····· 7

1.3.1 Typical Facial Expression Recognition Algorithms ····· 7

1.3.2 Existing Problems in Facial Expression Recognition ····· 13

1.4 Research Contents ····· 14

Chapter 2 Color Constancy Algorithm for Color Image Under Complex Illumination Conditions ····· 20

2.1 Introduction ····· 20

2.2 Correction of Color Deviation ····· 21

2.2.1 LoG Chrominance Edge Extraction ····· 23

2.2.2 White Balance Adjustment ····· 28

2.2.3 Experimental Results and Analysis ····· 30

2.3 Luminance Enhancement ····· 32

2.3.1 Retinex Enhancement Algorithm ····· 32

2.3.2 Color Retention Enhancement Algorithm ····· 35

2.3.3 Experimental Results and Analysis ····· 40

2.4 Fractional Step Color Constancy Algorithm ····· 42

2.5 Summary of This Chapter ····· 45

Chapter 3 Face Detection Algorithm with Multi-feature Fusion ····· 46

3.1 Introduction ····· 46

3.2 Skin Color Area Detection ····· 49

3.2.1 Common Color Space ····· 49

3.2.2 Skin Color Clustering Analysis ····· 55

3.2.3 Skin Color Area Detection Algorithm ····· 57

3.3 AdaBoost Face Detection Combined with Skin Color Features ····· 60

3.3.1 AdaBoost Algorithm ····· 62
3.3.2 AdaBoost Face Detection Algorithm Combined with Skin Color Features ····· 67
3.4 Face Authentication Based on Harris Corner Point Detection ···· 69
3.4.1 Principles for Harris Corner Point Detection ····· 69
3.4.2 Harris Corner Point Detection Algorithm ····· 71
3.4.3 Face Authentication Based on Harris Corner Point Detection ····· 73
3.5 Experimental Results and Analysis ····· 74
3.6 Summary of This Chapter ····· 76
Chapter 4 Facial Features Location ····· 78
4.1 Introduction ····· 78
4.2 Eye Location Based on the Robustness of Illuminated Expression ····· 79
4.2.1 Multi-scale Self-quotient Image ····· 80
4.2.2 Rough Location of Morphological Filtering ····· 81
4.2.3 Precise Eye Location ····· 85
4.2.4 Experimental Results and Analysis ····· 86
4.3 Location System of Key Color Facial Feature Point ····· 90
4.3.1 Overview of the System ····· 90
4.3.2 Eyes Location ····· 92
4.3.3 Mouth Location ····· 95
4.3.4 Experimental Results and Analysis ····· 97
4.4 Summary of This Chapter ····· 99
Chapter 5 Normalization of Facial Expression Image ····· 101
5.1 Introduction ····· 101
5.2 Rotation Normalization ····· 102
5.3 Size Normalization ····· 104
5.4 Illumination Normalization ····· 106
5.5 Experimental Results and Analysis ····· 110
5.6 Summary of This Chapter ····· 111
Chapter 6 Extraction of Facial Expression Features ····· 112
6.1 Introduction ····· 112
6.2 Gabor Local Statistical Features ····· 116

6.3 LBP Features ····· 120
6.3.1 Basic LBP and Its Improvement ····· 120
6.3.2 Uniform LBP Algorithm ····· 122
6.3.3 Expression Features Extracted by LBP Histogram ····· 124
6.4 Summary of This Chapter ····· 125
Chapter 7 Facial Expression Recognition Based on Supervised Orthogonal Locality Preserving Projection ····· 127
7.1 Introduction ····· 127
7.2 LPP Algorithm ····· 129
7.2.1 Laplacianface Algorithm ····· 129
7.2.2 Orthogonal Laplacianface Algorithm ····· 133
7.3 Expression Recognition with SOLPP ····· 135
7.3.1 LDA ····· 135
7.3.2 SOLPP ····· 136
7.3.3 Classification of Facial Expressions ····· 140
7.4 Experimental Results and Analysis ····· 141
7.5 Summary of This Chapter ····· 147
Chapter 8 Conclusion and Future Works ····· 148
8.1 Conclusion ····· 148
8.2 Future Works ····· 150
References ····· 153

Chapter 1
Introduction

1.1 Research Background and Significance

In social life, emotion plays an important role in coordinating the relationship between people. The research of emotion is more and more concerned by the society. Facial expression is a unique form for human beings to convey their intentions and emotional states. In interpersonal communication, facial expression is a very important way of communication besides voice. Psychological studies indicate that whether a listener likes your speech in human communication, 7% depends on your vocabulary, 38% depends on your voice, and the remaining 55% depends on your facial expressions[1]. Facial expressions, as the carrier of information, reflect much human behavior and convey the hidden information that the voice cannot do[2-3].

Facial expressions are not only a natural way for people to express emotions, but also the main symbol for people to identify emotions, which plays a very important role in affective computing. For human-computer interaction to achieve natural and harmonious communication, it is necessary for computers to acquire and analyze facial expression information. Therefore, the research on facial expression recognition method needs to be further developed. The computer vision technology is noninvasive, passive, cheap, and natural, so it naturally becomes the key technology in the process of facial expression recognition. While the in-depth research on such technologies as computer vision, image analysis and pattern recognition can contribute to the advancement of facial expression recognition methods. At

the same time, the study of facial expression recognition incorporates many other disciplines such as pattern recognition, image processing, analysis and understanding, computer graphics, cognitive science, neural computing, physiology, psychology, and so on. Therefore, the research on this issue could greatly enhance the development of the above-mentioned disciplines. What's more, the technology of facial expression recognition is also the core subject of the research of the intelligent human-computer interface that essentially is to train the machine to capture the changes of human emotions. With the advances in science, the computer after being trained can to a certain extent mimic the human behavior, but still does not have the human feelings. However, with the development of the facial expression recognition technology, the interface can be more natural to a certain extent so that the computer can respond to humans in accordance with the changes of human emotion. From this point, it can change people's way of life to some extent. In other words, the observation of the facial expression can be used to understand psychological states. This is, as the saying goes, to take the cue from a person's words and facial expressions. Nevertheless, the naked eyes cannot find some very fine changes of facial expressions, or it is easily to draw an opposite conclusion from that fine changes. After the introduction of machine recognition of facial expressions, the results can be obtained objectively and in real time. Therefore, we can expect facial expression recognition to replace lie detector in the security sector in the future.

In terms of medical care, for some mental patients, the expression analysis can be used as an auxiliary treatment. The analysis of patient's expression can help doctors analyze the patient's mental state, predict what would happen when the patient is in the face of diverse outside stimuli and thus take some responding precautionary measures, so that many incidences of accidents can be avoided. Facial expressions can also be used to supplement the lip language to help those having hearing problem communicate with the world they live in.

On the commercial side, the devices that can keep track of user's facial

expressions will certainly come into being in the near future. The application of such technology in videophone or teleconferencing is undoubtedly of great significance for strengthening domestic and international business cooperation. If the technology is applied to the automotive, the machine vision equipment can detect the driver's fatigued state and then alert the drive. This equipment can analyze the real-time mental state of the driver and judge whether the driver's fatigue will exert negative effect on the driver or the fatigue will make the driver sleep while driving, it then will take the necessary measures such as alarming or playing exciting music to prevent potential traffic accidents.

In addition, if the existing recreational machines that have no emotions can recognize the human emotions, and adjust the strategy in accordance with the users' emotional changes, it can provide individualized services and greatly enhance the user's entertainment interest. Moreover, an intelligent toy with personality and the ability to understand and express emotions (such as an electronic pet that can communicate with its owner) is sure to be more popular with children and even adults. Furthermore, in the process of educational research on children, we observe the behavior and expression change reaction of children in specific scenes by setting up a series of specific scenes, and then we accordingly analyze some quality elements such as personality temperament, and understand the advantages and defects of their personality and enlarge and guide them. This will have a profound impact on the cultivation of mental health for the next generation of our nation.

Therefore, facial expression recognition has important applications in linguistics, medicine, business, children's education, and so on. As far as computer science is concerned, the study of facial expression recognition is of great significance for realizing natural human-computer interaction and automatic image understanding. Therefore, the study of facial expression automatic recognition is of great theoretical significance and practical value.

1.2 Overview of Facial Expression Recognition

The facial expressions and the changes of expressions are quite complex. Ekman and Friesen defined six basic expressions, including surprise, fear, disgust, anger, happiness and sadness, which are widely used in the academic studies[4]. Because different reasons or motivations will result in different expressions, or some mixed and complicated expressions, the types and the level of the expression vary accordingly. Thus, the manifestations and characteristics of the expressions will also vary. For example, fear may be accompanied by sadness, anger, disgust, etc. In order to have a better understanding of the expressions, the characteristics of each basic facial expressions are summarized in Table 1-1.

Table 1-1 The characteristics of basic facial expressions

Expressions	Forehead/Eyebrows	Eyes	Lower Part of the Face
Surprise	eyebrows raise, the skin under the eye brows stretch, and the wrinkles (may) cut across the forehead	eyes widen, upper eyelids raise and the lower eyelids droop, the white of the eye is exposed at the upper or lower edge of the pupils	mandible loweres and mouth opens, lip and teeth separate, but mouth remains relaxed
Fear	eyebrows raise and pull together, the nose wrinkles	raise upper eyelids, tense lower eyelids	mouth opens and lips either slightly tenses and pull back or stretch horizontally back
Disgust	lowered eyebrows and upper eyelids	wrinkles appear in the lower part of the eyelids, pull up the cheeks but not tense	upper lip raises, the lower lip and the upper lip clench, upper lip pulls up, the slight pulling down of lip corners, lip slightly raises, nose wrinkling appeares, pushes up cheeks
Anger	eyebrows down and together, vertical nose wrinkles	lower eyelids tense, raise or not raise, upper eyelids tense, eyebrows lower, eyes glare, prominent eyes	two basic locations for lips: close and stretch horizontally or pull down; open, as if to cry, the nostrils may open wide
Happiness	eyebrows slightly bend	wrinkles may appear under the lower eyelids which may be prominent but not tense, crow's feet wrinkle	lip corner pulls back and raises, mouth may open, teeth may be exposed, a wrinkle stretches from nose to mouth, and cheeks push up

Continued

Expressions	Forehead/Eyebrows	Eyes	Lower Part of the Face
Sadness	the inner eyelids pull together, raise and pull the skin under the eyebrows	upper eyelids of the inner eye raise	lip corners pull down, lip corners may tremble

The process of facial expression recognition mainly includes image preprocessing, face detection, facial features location, facial expression features extraction, and facial expressions classification. Figure 1-1 shows the flow chart of facial expression recognition. In order to realize facial expression recognition automatically, computer needs to detect human face from given static image or video sequence image firstly. Then position facial features. Next extract expression features, and compare them with the existing ones. Finally determine facial expression classification in the image.

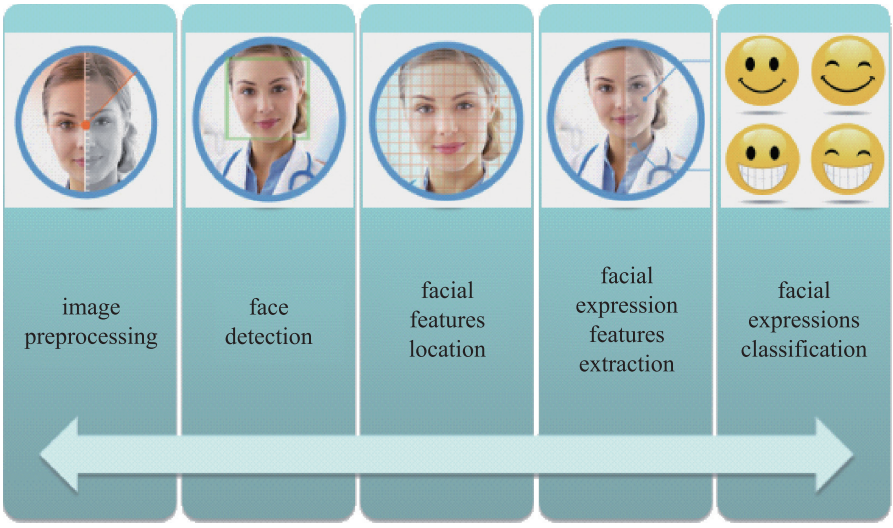


Figure 1-1 The flow chart of facial expression recognition

As shown in Figure 1-1, the key steps for facial expression recognition are as follows:

（1）Image preprocessing. Firstly, image preprocessing is necessary before face detection. The color deviation and uneven illumination should be eliminated effectively so that human face can be detected correctly.