



UNIVERSITI PUTRA MALAYSIA

***SINGLE HAND INDIAN CLASSICAL GESTURE RECOGNITION BASED ON
DISCRETE WAVELET TRANSFORM AND DISCRETE COSINE TRANSFORM
FEATURE EXTRACTION***

KAVITHA JAGANATHAN

FSKTM 2015 24



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TRANSFORM FEATURE EXTRACTION**

By

KAVITHA JAGANATHAN

**Thesis submitted to the School Graduate Studies, Universiti Putra Malaysia, in
fulfilment of the Requirement for the Master of Science**

September 2015

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DEDICATIONS

I would like thank the almighty GOD to give me all the courage and strength in finishing this research. Secondly would like to express my gratitude to my supervisor, Dr.Lili Nurliyana Binti Abdullah. I would like to dedicate this thesis to my husband Ambrose Solomon, dad Dr.M.Jaganathan and mom Mrs.M.Pushpalechumy.

KAVITHA JAGANATHAN
2015

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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KAVITHA JAGANTHAN

September 2015

Chairperson : Lili Nurliyana Binti Abdullah, PhD
Faculty : Computer Science and Information Technology

Hand gestures in Bharatanatyam dance carry valuable information. Learning the meaning of hand gesture, mimic and practice them with the best way and high matching for the people who want to be expert in this field is necessary. Therefore, hand gesture recognition system can be implemented to help people to learn it effectively and efficiently. In this thesis, a combined feature extraction method based on the Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) is proposed. DWT with two level decompositions is applied to the image by size of 128×128 . Two-dimensional DCT is then applied and convert the coefficients of DCT to vector. Finally, neuro fuzzy classifier is used to classify the given images in some given classes. The results are shown in a graphical format to prepare a good understanding in final stage for the user. A suitable number of images with good illumination for different applications have been created. Many types of image processing techniques like scaling and translation can also be applied to the original database and make ready more options for any future study. The experimental results show that the proposed method has good performance in most of single hand gestures. The dataset of single hand gesture in Bharatanatyam dance has been successfully created and it could serve as a benchmark data set as well. Our proposed system is able to recognize single hand gesture with the accuracy of 93%. At the testing stage, 130 out of 140 images of single hand gestures are correctly classified by the proposed graphic user interface GUI. This is because the parameters identified were the right signal, which gave the best 70 features to be classified and recognized.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

**PENGECAMAN GERAK ISYARAT TRIAN TRADISI INDIA TANGAN
TUNGGAL BERASASKAN PENGEKSTRAKAN SIFAT DISKERET
WAVELET TRANSFORM DAN DISKRET KOSINUS TRANSFORM**

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Gerak isyarat tangan dalam tarian Bharatanatyam membawa informasi yang berguna. Mempelajari maksud gerak isyarat tangan, mimik dan menjalani latihan dengan cara yang terbaik amat diperlukan oleh individu yang berminat dalam bidang ini. Oleh itu, sistem pengecaman gerak isyarat tangan harus dibangunkan untuk membantu golongan yang mahu mempelajarinya secara efektif dan cekap. Dalam tesis ini, kaedah pengekstrakan sifat yang telah digabungkan iaitu *Discrete Wavelet Transform* (DWT) dan *Discrete Cosine Transform* (DCT) telah dicadangkan. DWT dengan dua aras leraian diaplikasikan pada imej bersaiz 128 x 128. DCT dengan 2 dimensi kemudiannya diaplikasikan pada bahagian terpilih dan koefisien DCT tersebut akan ditukar kepada vektor. Akhirnya, pengelas *neuro fuzzy* digunakan untuk mengelaskan imej yang diberi pada kelas-kelas yang tertentu. Hasil kajian dipaparkan dalam format grafik bagi memudahkan pengguna akhir memahami hasil yang ditemui. Hasil eksperimen menunjukkan bahawa kaedah yang dicadangkan mempunyai prestasi yang baik pada gerak isyarat tangan tunggal. Beberapa sesuai imej dengan pencahayaan yang baik untuk aplikasi yang berbeza telah diwujudkan. Banyak jenis teknik-teknik pemprosesan imej seperti putaran, bersisik, dan terjemahan juga boleh memohon kepada pangkalan data asal dan bersedia membuat pilihan bagi mana-mana kajian. Sistem cadangan tesis ini dapat mengenali isyarat tangan tunggal dengan had ketepatan 93%. 130 daripada 140 imej isyarat tangan tunggal dengan betul diklasifikasikan oleh sistem yang dicadangkan. Ini adalah kerana parameter yang dikenal pasti adalah isyarat yang tepat yang memberikan yang terbaik 70 ciri untuk dikelaskan dan diiktiraf.

ACKNOWLEDGEMENTS

Thank God for everything during my voyage of knowledge exploration. First and foremost, I would like to express my gratitude to my supervisor, Dr.Lili Nurliyana Binti Abdullah to who I am indebted to for the whole of my life. I wish I could repay her. Next, I would like to forward my warmest appreciation to the supervisory committee for their guidance, suggestions and advice throughout this work to make it a success.

My deepest thanks go to all the lecturers and staff in my department who are so kind and assisted me during my study. I would like to express my highest appreciation to my beloved husband Ambrose Solomon, dad Dr.M.Jaganathan, mom Mrs. Pusphalechumy, family members and friends who supported me in this study.

My sincere thanks goes to my all my friends, especially Julie, Mohammad and others for their kindness and moral support during my study. I thank them for the friendship and memories. To those who indirectly contributed to this research, your kindness means a lot to me.

I certify that a Thesis Examination Committee has met on 29 September 2015 to conduct the final examination of Kavitha Jaganathan on her thesis entitled "Single Hand Indian Classical Gesture Recognition Based on Discrete Wavelet Transform and Discrete Cosine Transform Feature Extraction" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The culture of India is rich and has a lot of diversities. The elements of India's cultures include religions, languages and literatures, performing arts (dances, music and drama), clothing, cuisines and so on. These diversities have had a deep impact across the globe.

The Indian classical dance is the highest form of art for Indian people and there are many variations of the dance forms. It includes Bharanatyam, Odissi, Kuchipudi, Kathakali, Kathak and so on. Bharanatyam has originated in the temples of Tamil Nadu, South India and executed mostly by women. It is named after the fifth Veda and considered to be the oldest dance form in India. The performer should have the knowledge of the features of the Bharanatyam dance style in order to perform it. The features are emphasized in the dance style as it conveys different kind of emotions to the spectator and act as an approach of communication.

Since the hand gesture is one of the important features in Bharanatyam dance, it is noteworthy to conduct a research on hand gesture recognition for the dance as it can bring some benefits to the people who wants to learn the dance via the internet or interactive multimedia products. This thesis intends to implement a fusion of image processing techniques with the aim of improvising the recognition rate of hand gesture movement in Bharatanatyam dance.

1.2 Motivation and Background of Study

In general, there are four vital techniques which include Hasta (expressive hand gestures), Karanas (transitional movements), Adavus (series of steps) and Bhedas, eyes and neck movements in Bharanatyam dance (Verma, 2009) Hasta refers to a variety of hand gestures used by the dancer and regarded as a significant feature of Bharanatyam dance. It can be classified into two categories: i) Asamyukta Hasta (single hand gestures); and ii) Samyukta Hasta (double hand gestures). There are 28 Asamyukta Hasta and 24 Samyukta Hasta. The Asamyukta Hasta is done using a single hand which includes a hand gesture of Pataka (flag), Kartarimukha (arrow shaft), Mayura (peacock), Ardachandra (half-moon), to name a few. These single hand gestures are relatively unchanged over the years (Verma, 2009).

Single hand gesture recognition of dance form is one of the important research areas in computer vision field with many potential applications. It is firstly required to offer more accessibility and lesson to the common people, especially the beginner

dancer, to learn the dance form and as self-assessment (Mozarkar & Warnekar, 2013).

In addition, it is essential to conduct a study on the feature extraction method in gesture recognition as it is one of the main phases in classification task. Feature extraction begins with an initial set of data and then it builds derived values, which is informative and assists the generalization step in the task. It also facilitates better human interpretation in image processing and pattern recognition field. Given a single hand gesture image, our proposed approach aims to detect and classify the gesture that was performed with higher accuracy.

1.3 Problem Statement

The hand gesture is one of the prominent features of Bharanatyam form. To the best of our knowledge, a method to recognize and classify single hand gesture in Bharanatyam dance is still lack in the literature. Most of the previous dance gesture studies are focusing on the other body parts motion or skeleton structure for dance gesture recognition (Dong *et al.*, 2006; Heryadi *et al.*, 2012). (Saha *et al.*, 2013(a)) research shows a accuracy of only 85.1% and some of the other research on single hand gesture in Bharanatyam had shown promising performance but there is still room for improvement in terms of recognition rate (Hariharan *et al.*, 2011)

The DCT is used transformation for data compression. It is an orthogonal transform, which has a fixed set of image and is better compared to Edge Oriented Histogram. The system gives better results with higher resolution web cameras. The segmentation of image gives better results if the light conditions are good according to Pansare, J. R., Kadam, S., Dhawade, O., & Chauhan, P. (2013). In this paper, DWT is applied on the obtained images and some features are extracted using the wavelet coefficients. Experimental results showed recognize 32 selected PSL alphabets with an average classification accuracy of 94.06% (Karami, A., Zanj, B., & Sarkaleh, A. K. (2011)). Therefore, we attempt to propose a combined feature extraction method to recognize the single hand gestures in Bharanatyam dance in order to fill the research gap.

(Hsieh, C. C., Liou, D. H., & Lee, D. (2010, July)) paper shows that they have developed a simple and fast motion history image based method. Four groups of haar-like directional patterns were trained for the up, down, left, and right hand gestures classifiers. Together with fist hand and waving hand gestures, there were totally six hand gestures defined. Five persons doing 250 hand in front of the web camera were tested. Experimental results show that the processing time is 3.81 ms per frame which inspired our research to reduce our complexity computing.

1.4 Research Objectives

The main objective of this thesis is to propose a single hand gesture recognition system for identification of single hand gesture in Bharatanatyam dance form based on contemporary feature extraction and pattern classification technique.

The sub-objectives are as follows:

- I. To improve the hand gesture extraction using the combination of discrete wavelet transform and discrete cosine transform.
- II. To increase the recognition rate performance in single hand gesture recognition.
- III. To reduce the complexity of computing.

1.5 Significance of Study

It is very significant to conduct a study on hand gesture recognition in Bharatanatyam dance since the hand gestures carry valuable information and thus, it is crucial for the dancer to perform the dance correctly. As the technology is advancing rapidly, it becomes easier to learn the hand gestures in Bharatanatyam dance via the internet or any interactive media.

Our proposed approach can serve as learning tool or program for dancer who is interested to learn the hand gesture in Bharatanatyam dance. In this study, the gesture is focused on the single hand as it is the fundamental step and one of the most prominent features in Bharatanatyam dance. Hence, the conduct of the study is very significant in assisting dancer to learn the basic step in this dance. In addition, it is also important to highlight the use of the combination of discrete wavelet transform and discrete cosine transform in feature extraction phase, which increases the performance of the overall recognition system. The output of this study can be used as future reference and benchmarking.

1.6 Scope of Study

The proposed scope of work aims at recognizing automatically an unknown hand gesture, simultaneously measuring the proximity of an unknown hand gesture to a known gesture, which enables dancer enhancement towards the performance. Scope of study of the thesis are

- x indian classical hand gesture data set creation
- x skin color detection
- x feature extraction of Discrete Wavelet Transform and Discrete Cosine Transform
- x single hand gestures recognition rate comparison
- x neuro fuzzy classification
- x real time user interface for e-learning

1.7 Thesis Organization

This thesis consists of five chapters

- Chapter 1 discusses background, statement of problem, research objectives, significance and scope of study.
- Chapter 2 elaborates the previous works that have been done.
- Chapter 3 the methodology adapted to address the problem statement in detail.
- Chapter 4 presents the result of our proposed method and its discussion.
- Chapter 5 is the recommendations for future works and major conclusion is provided.

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REFERENCES

- Ahmeda, S. H., Alexanderb, T. C., & Anagnostopoulosb, G. C. (2006). Real-time, Static and Dynamic Hand Gesture Recognition for Human-Computer Interaction: IEEE.
- Birk, H., Moeslund, T. B., & Madsen, C. B. (1997). *Real-time recognition of hand alphabet gestures using principal component analysis*. Proceedings of the Scandinavian Conference on Image Analysis.
- Bowden, R., Zisserman, A., Kadir, T., & Brady, M. (2003). *Vision based interpretation of natural sign languages*. Paper presented at the International Conference Computer Vision System, Graz, Austria.
- Benedetto, J. J., Czaja, W., & Ehler, M. (2013). Wavelet packets for time-frequency analysis of multispectral imagery. *GEM-International Journal on Geomathematics*, 4(2), 137-154.
- Cetişli, B., & Barkana, A. (2010). Speeding up the scaled conjugate gradient algorithm and its application in neuro-fuzzy classifier training. *Soft computing*, 14(4), 365-378.
- Chai, D., & Ngan, K. N. (1999). Face segmentation using skin-color map in videophone applications. *Circuits and Systems for Video Technology, IEEE Transactions on*, 9(4), 551-564.
- Chakraborty, P., Sarawgi, P., Mehrotra, A., Agarwal, G., & Pradhan, R. (2008). *Hand gesture recognition: A comparative study*. Proceedings of the International MultiConference of Engineers and Computer Scientists.
- Chaudhary A, Raheja JL, Das K, Raheja S (2011) Intelligent approaches to interact with machines using hand gesture recognition in natural way: a survey. *Int J Comput Sci Eng Survey (IJCSSES)* 2(1):122-133
- Chen, F.-S., Fu, C.-M., & Huang, C.-L. (2003). Hand gesture recognition using a real-time tracking method and hidden Markov models. *Image and Vision Computing*, 21(8), 745-758.
- Corera, S., & Krishnarajah, N. (2011). Capturing hand gesture movement: a survey on tools techniques and logical considerations. *Proceedings of chi sparks*.
- Derpanis, K. G. (2004). A review of vision-based hand gestures. http://cvr.yorku.ca/members/gradstudents/kosta/publications/file_Gesture_review.pdf
- Dong, Q., Wu, Y., & Hu, Z. (2006). Gesture recognition using quadratic curves *Computer Vision ACCV 2006* (pp. 817-825): Springer.

- Elmezain, M., Al-Hamadi, A., & Michaelis, B. (2008). Real-time capable system for hand gesture recognition using hidden markov models in stereo color image sequences.
- Feng, K.-p., & Yuan, F. (2013). *Static hand gesture recognition based on HOG characters and support vector machines*. Instrumentation and Measurement, Sensor Network and Automation (IMSNA), 2013 2nd International Symposium on.
- Ghosh, D. K., & Ari, S. (2011). *A static hand gesture recognition algorithm using k-mean based radial basis function neural network*. Information, Communications and Signal Processing (ICICS) 2011 8th International Conference on.
- Gose, E., Johnsonbaugh, R., & Jost, S. (1996). *Pattern recognition and image analysis*: Prentice-Hall, Inc.
- Hariharan, D., Acharya, T., & Mitra, S. (2011). Recognizing hand gestures of a dancer. *Pattern recognition and machine intelligence* (pp. 186-192): Springer.
- Heryadi, Y., Ivan Fanany, M., & Arymurthy, A. M. (2012). Grammar of Dance Gesture from Bali Traditional Dance. *International Journal of Computer Science Issues (IJCSI)*, 9(6).
- Hsu, R.-L., Abdel-Mottaleb, M., & Jain, A. K. (2002). Face detection in color images. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 24(5), 696-706.
- Hsieh, C. C., Liou, D. H., & Lee, D. (2010, July). A real time hand gesture recognition system using motion history image. In *Signal Processing Systems (ICSPS), 2010 2nd International Conference on* (Vol. 2, pp. V2-394). IEEE.
- Hongjun Jia and Aleix M. Martinez, (2008) *Face Recognition with Occlusions in the Training and Testing Sets* 8th IEEE International Conference on IEEE.
- John J. Benedetto, Wojciech Czaja, Martin Ehler (2013), *Wavelet packets for time-frequency analysis of multispectral imagery*, GEM - International Journal on Geomathematics Volume 4, Issue 2, pp 137-154.
- Kaâniche, M. B. (2009). Gesture recognition from video sequences (Doctoral dissertation, Université Nice Sophia Antipolis).
- Kalgaonkar, K., & Raj, B. (2009, April). *One-handed gesture recognition using ultrasonic Doppler sonar*. In Acoustics, Speech and Signal Processing, 2009. ICASSP 2009. IEEE International Conference on (pp. 1889-1892). IEEE.

- Kanungo, T., Mount, D. M., Netanyahu, N. S., Piatko, C. D., Silverman, R., & Wu, A. Y. (2002). *An efficient k-means clustering algorithm: Analysis and implementation*. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 24(7), 881-892.
- Karami, A., Zanj, B., & Sarkaleh, A. K. (2011). Persian sign language (PSL) recognition using wavelet transform and neural networks. *Expert Systems with Applications*, 38(3), 2661-2667.
- Lamar, M. V., Bhuiyan, M. S., & Iwata, A. (1999). *Hand alphabet recognition using morphological PCA and neural networks*. *Neural Networks, 1999. IJCNN'99. International Joint Conference on*.
- Liu, Y., Gan, Z., & Sun, Y. (2008). *Static hand gesture recognition and its application based on support vector machines*. *Software Engineering, Artificial Intelligence, Networking, and Parallel/Distributed Computing, 2008. SNPD'08. Ninth ACIS International Conference on*.
- Lockton, R., & Fitzgibbon, A. W. (2002). *Real-time gesture recognition using deterministic boosting*. Paper presented at the BMVC.
- Lu, W. L., & Little, J. J. (2006, June). *Simultaneous tracking and action recognition using the pca-hog descriptor*. In *Computer and Robot Vision, 2006. The 3rd Canadian Conference on* (pp. 6-6). IEEE.
- Maraqqa, M., & Abu-Zaiter, R. (2008). *Recognition of Arabic Sign Language (ArSL) using recurrent neural networks*. Paper presented at the *Applications of Digital Information and Web Technologies, 2008. ICADIWT 2008. First International Conference on the*.
- Maung, T. H. H. (2009). *Real-Time Hand Tracking and Gesture Recognition System Using Neural Networks*. *Proceedings of World Academy of Science: Engineering & Technology*, 50.
- Mitra, S., & Acharya, T. (2007). *Gesture recognition: A survey*. *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on*, 37(3), 311-324.
- Moeslund, T. B., & Granum, E. (2001). A survey of computer vision-based human motion capture. *Computer Vision and Image Understanding*, 81(3), 231-268.
- Mozarkar, S., & Warnekar, C. (2013). *Recognizing Bharatnatyam Mudra Using Principles of Gesture Recognition*. *International Journal of Computer Science and Network* 2(4), 7.
- Murthy, G. R. S., & Jadon, R. S. (2009). A review of vision based hand gestures recognition. *International Journal of Information Technology and Knowledge Management*, 2(2), 405-410.

- Pansare, J. R., Kadam, S., Dhawade, O., & Chauhan, P. (2013). Real Time Static Hand Gesture Recognition System in Simple Background for Devanagari Number System. *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*, 2(3), pp-0938.
- Pentland, A., Moghaddam, B., & Starner, T. (1994). *View-based and modular eigenspaces for face recognition*. Computer Vision and Pattern Recognition, 1994. Proceedings CVPR'94., 1994 IEEE Computer Society Conference on.
- Priyal, S. P., & Bora, P. K. (2010). *A study on static hand gesture recognition using moments*. Signal Processing and Communications (SPCOM), 2010 International Conference on.
- Rajam, P. S., & Balakrishnan, G. (2010). *Indian sign language recognition system to aid deaf-dumb people*. Computing Communication and Networking Technologies (ICCCNT), 2010 International Conference on.
- Ramamoorthy, A., Vaswani, N., Chaudhury, S., & Banerjee, S. (2003). Recognition of dynamic hand gestures. *Pattern Recognition*, 36(9), 2069-2081.
- Rao, K. R., Yip, P., & Rao, K. R. (1990). *Discrete cosine transform: algorithms, advantages, applications* (Vol. 226): Academic press Boston.
- Rautaray, S. S., & Agrawal, A. (2012). Vision based hand gesture recognition for human computer interaction: a survey. *Artificial Intelligence Review*, 1-54.
- Saha, S., Ghosh, L., Konar, A., & Janarthanan, R. (2013(b)). *Fuzzy L Membership Function Based Hand Gesture Recognition for Bharatanatyam Dance*. Computational Intelligence and Communication Networks (CICN), 2013 5th International Conference on.
- Saha, S., Konar, A., Gupta, D., Ray, A., Sarkar, A., Chatterjee, P., & Janarthanan, R. (2014, January). Bharatanatyam hand gesture recognition using polygon representation. In *Control, Instrumentation, Energy and Communication (CIEC), 2014 International Conference on* (pp. 563-567). IEEE.
- Saha, S., Ghosh, S., Konar, A., & Nagar, A. K. (2013(a)). *Gesture Recognition from Indian Classical Dance Using Kinect Sensor*. Computational Intelligence, Communication Systems and Networks (CICSyN), 2013 Fifth International Conference on.
- Sandeep.K, Gaganpreet.K, Dr.Dheerendra.S. *Comparative Analysis Of Haar And Coiflet Wavelets Using Discrete Wavelet Transform In Digital Image Compression*. International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 3, (2013), pp.669-673.
- Shangeetha, R. K., Valliammai, V., & Padmavathi, S. (2012, 14-15 Dec. 2012). *Computer vision based approach for Indian Sign Language character recognition*. Machine Vision and Image Processing (MVIP), 2012 International Conference on.

- Su, M. C. (2000). A fuzzy rule-based approach to spatio-temporal hand gesture recognition. *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on*, 30(2), 276-281.
- Sun, C.-T., & Jang, J.-S. (1993). *A neuro-fuzzy classifier and its applications*. Paper presented at the Fuzzy Systems, 1993., Second IEEE International Conference on.
- S.Nagarajan and T.S.Subashini. *Static Hand Gesture Recognition for Sign Language Alphabets using Edge Oriented Histogram and Multi Class SVM*, (2013) International Journal of Computer Applications. Volume 82,0975 – 8887.
- Symeonidis, K. (1996). Hand gesture recognition using neural networks. *Neural Networks*, 13(5.1).
- Trigueiros, P., Ribeiro, F., & Reis, L. P. (2012). *A comparison of machine learning algorithms applied to hand gesture recognition*. Information Systems and Technologies (CISTI), 2012 7th Iberian Conference on.
- Verma, M. (2009). *Hastas Bharatanatyam: Origin, Styles and Techniques* (pp. 20): Abhishek Publishers.
- Vieriu, R.-L., Mironica, I., & Goras, B.-T. (2013). *Background invariant static hand gesture recognition based on Hidden Markov Models*. Signals, Circuits and Systems (ISSCS), 2013 International Symposium on.
- Yeasin, M., & Chaudhuri, S. (2000). Visual understanding of dynamic hand gestures. *Pattern Recognition*, 33(11), 1805-1817.
- Wachs, J. P., Kölsch, M., Stern, H., & Edan, Y. (2011). Vision-based hand-gesture applications. *Communications of the ACM*, 54(2), 60-71.
- Ying, W. (2013). The Semi-supervised Immune Classifier Generation Algorithm Based on Data Clustering.... *Journal of Computational Information Systems*, 9(9), 3407-3414.
- Yun, L., Lifeng, Z., & Shujun, Z. (2012). A Hand Gesture Recognition Method Based on Multi-Feature Fusion and Template Matching. *Procedia Engineering*, 29, 1678-1684.