

**MAKALAH ILMIAH  
PROSIDING SEMINAR INTERNASIONAL  
TERINDEKS SCOPUS**

**The 21st International Conference on Neural Information  
Processing  
ICONIP 2014**



Judul:

Adaptive Wavelet Extreme Learning Machine (AW-ELM) for Index  
Finger Recognition Using Two-Channel Electromyography

disusun oleh:  
Khairul Anam dkk

**JURUSAN TEKNIK ELEKTRO  
FAKULTAS TEKNIK  
UNIVERSITAS JEMBER  
2017**

---

Diseminarkan di Kuching, Malaysia  
3 – 6 November 2014

Chu Kiong Loo Keem Siah Yap  
Kok Wai Wong Andrew Teoh  
Kaizhu Huang (Eds.)

LNCS 8834

# Neural Information Processing

21st International Conference, ICONIP 2014  
Kuching, Malaysia, November 3–6, 2014  
Proceedings, Part I

1  
Part I

*Commenced Publication in 1973*

Founding and Former Series Editors:

Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

### Editorial Board

David Hutchison

*Lancaster University, UK*

Takeo Kanade

*Carnegie Mellon University, Pittsburgh, PA, USA*

Josef Kittler

*University of Surrey, Guildford, UK*

Jon M. Kleinberg

*Cornell University, Ithaca, NY, USA*

Friedemann Mattern

*ETH Zurich, Switzerland*

John C. Mitchell

*Stanford University, CA, USA*

Moni Naor

*Weizmann Institute of Science, Rehovot, Israel*

C. Pandu Rangan

*Indian Institute of Technology, Madras, India*

Bernhard Steffen

*TU Dortmund University, Germany*

Demetri Terzopoulos

*University of California, Los Angeles, CA, USA*

Doug Tygar

*University of California, Berkeley, CA, USA*

Gerhard Weikum

*Max Planck Institute for Informatics, Saarbruecken, Germany*

Digital Repository Universitas Jember

Chu Kiong Loo Keem Siah Yap  
Kok Wai Wong Andrew Teoh  
Kaizhu Huang (Eds.)

# Neural Information Processing

21st International Conference, ICONIP 2014  
Kuching, Malaysia, November 3-6, 2014  
Proceedings, Part I

 Springer

# Digital Repository Universitas Jember

## Volume Editors

Chu Kiong Loo  
University of Malaya, Kuala Lumpur, Malaysia  
E-mail: ckloo.um@um.edu.my

Keem Siah Yap  
Universiti Tenaga Nasional, Selangor, Malaysia  
E-mail: yapkeem@uniten.edu.my

Kok Wai Wong  
Murdoch University, Murdoch, WA, Australia  
E-mail: k.wong@murdoch.edu.au

Andrew Teoh  
Yonsei University, Seoul, South Korea  
E-mail: bjteoh@yonsei.ac.kr

Kaizhu Huang  
Xi'an Jiaotong-Liverpool University, Suzhou, China  
E-mail: kaizhu.huang@xjtlu.edu.cn

ISSN 0302-9743

ISBN 978-3-319-12636-4

DOI 10.1007/978-3-319-12637-1

Springer Cham Heidelberg New York Dordrecht London

e-ISSN 1611-3349

e-ISBN 978-3-319-12637-1

Library of Congress Control Number: 2014951688

LNCS Sublibrary: SL 1 – Theoretical Computer Science and General Issues

© Springer International Publishing Switzerland 2014

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

*Typesetting:* Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

## Preface

This volume is part of the three-volume proceedings of the 21st International Conference on Neural Information Processing (ICONIP 2014), which was held in Kuching, Malaysia, during November 3–6, 2014. The ICONIP is an annual conference of the Asia Pacific Neural Network Assembly (APNNA). This series of ICONIP conferences has been held annually since 1994 in Seoul and has become one of the leading international conferences in the area of neural networks.

ICONIP 2014 received a total of 375 submissions by scholars from 47 countries/regions across six continents. Based on a rigorous peer-review process where each submission was evaluated by at least two qualified reviewers, a total of 231 high-quality papers were selected for publication in the reputable series of *Lecture Notes in Computer Science* (LNCS). The selected papers cover major topics of theoretical research, empirical study, and applications of neural information processing research. ICONIP 2014 also featured a pre-conference event, namely, the Cybersecurity Data Mining Competition and Workshop (CDMC 2014) which was held in Kuala Lumpur. Nine papers from CDMC 2014 were selected for a Special Session of the conference proceedings.

In addition to the contributed papers, the ICONIP 2014 technical program included a keynote speech by Shun-Ichi Amari (RIKEN Brain Science Institute, Japan), two plenary speeches by Jacek Zurada (University of Louisville, USA) and Jürgen Schmidhuber (Istituto Dalle Molle di Studi sull'Intelligenza Artificiale, Switzerland). This conference also featured seven invited speakers, i.e., Akira Hirose (The University of Tokyo, Japan), Nikola Kasabov (Auckland University of Technology, New Zealand), Soo-Young Lee (KAIST, Korea), Derong Liu (Chinese Academy of Sciences, China; University of Illinois, USA), Kay Chen Tan (National University of Singapore), Jun Wang (The Chinese University of Hong Kong), and Zhi-Hua Zhou (Nanjing University, China).

We would like to sincerely thank Honorary Chair Shun-ichi Amari, Mohd Amin Jalaludin, the members of the Advisory Committee, the APNNA Governing Board for their guidance, the members of the Organizing Committee for all their great efforts and time in organizing such an event. We would also like to take this opportunity to express our deepest gratitude to all the technical committee members for their professional review that guaranteed high quality papers.

We would also like to thank Springer for publishing the proceedings in the prestigious LNCS series. Finally, we would like to thank all the speakers, authors,

and participants for their contribution and support in making ICONIP 2014 a successful event.

November 2014

Chu Kiong Loo  
Keem Siah Yap  
Kok Wai Wong  
Andrew Teoh  
Kaizhu Huang



# Digital Repository Universitas Jember

## Organization

### Honorary Chairs

Shun-Ichi Amari

RIKEN, Japan

Mohd Amin Jalaludin

University of Malaya, Malaysia

### General Chair

Chu Kiong Loo

University of Malaya, Malaysia

### General Co-chairs

Yin Chai Wang

University Malaysia Sarawak, Malaysia

Weng Kin Lai

Tunku Abdul Rahman University College,  
Malaysia

### Program Chairs

Kevin Kok Wai Wong

Murdoch University, Australia

Andrew Teoh

Yonsei University, Korea

Kaizhu Huang

Xi'an Jiaotong-Liverpool University, China

### Publication Chairs

Lakhmi Jain

University of South Australia, Australia

Chee Peng Lim

Deakin University, Australia

Keem Siah Yap

Universiti Tenaga Nasional, Malaysia

### Registration Chair and Webmaster

Yun Li Lee

Sunway University, Malaysia

### Local Organizing Chairs

Chong Eng Tan

University Malaysia Sarawak, Malaysia

Kai Meng Tay

University Malaysia Sarawak, Malaysia



## **Workshop and Tutorial Chairs**

Chen Change Loy	Chinese University of Hong Kong, SAR China
Ying Wah Teh	University of Malaya, Malaysia
Saeed Reza	University of Malaya, Malaysia
Tutut Harewan	University of Malaya, Malaysia

## **Special Session Chairs**

Thian Song Ong	Multimedia University, Malaysia
Siti Nurul Huda Sheikh Abdullah	Universiti Kebangsaan Malaysia, Malaysia

## **Financial Chair**

Ching Seong Tan	Multimedia University, Malaysia
-----------------	---------------------------------

## **Sponsorship Chairs**

Manjeevan Seera	University of Malaya, Malaysia
John See	Multimedia University, Malaysia
Aamir Saeed Malik	Universiti Teknologi Petronas, Malaysia

## **Publicity Chairs**

Siong Hoe Lau	Multimedia University, Malaysia
Khairul Salleh Mohamed Sahari	Universiti Tenaga Nasional, Malaysia

## **Asia Liaison Chairs**

ShenShen Gu	Shanghai University, China
-------------	----------------------------

## **Europe Liaison Chair**

Wlodzislaw Duch	Nicolaus Copernicus University, Poland
-----------------	--

## **America Liaison Chair**

James T. Lo	University of Maryland, USA
-------------	-----------------------------

## Advisory Committee

Lakshmi Jain, Australia  
David Gao, Australia  
BaoLiang Lu, China  
Ying Tan, China  
Jin Xu, China.  
Irwin King, Hong Kong, SAR China  
Jun Wang, Hong Kong, SAR China  
P. Balasubramaniam, India  
Kunihiko Fukushima, Japan  
Shiro Usui, Japan  
Minho Lee, Korea  
Muhammad Leo Michael Toyad  
Abdullah, Malaysia  
Mustafa Abdul Rahman, Malaysia  
Narayanan Kulathuramaiyer,  
Malaysia  
David Ngo, Malaysia

Siti Salwah Salim, Malaysia  
Wan Ahmad Tajuddin Wan Abdullah,  
Malaysia  
Wan Hashim Wan Ibrahim, Malaysia  
Dennis Wong, Malaysia  
Nik Kasabov, New Zealand  
Arnulfo P. Azcarraga, Phillipines  
Wlodzislaw Duch, Poland  
Tingwen Huang, Qatar  
Meng Joo Err, Singapore  
Xie Ming, Singapore  
Lipo Wang, Singapore  
Jonathan H. Chan, Thailand  
Ron Sun, USA  
De-Liang Wang, USA  
De-Shuang Huang, China

## Technical Committee

Ahmad Termimi Ab Ghani  
Mark Abernethy  
Adel Al-Jumaily  
Leila Aliouane  
Cesare Alippi  
Ognjen Arandjelovic  
Sabri Arik  
Mian M. Awais  
Emili Balaguer-Ballester  
Valentina Emilia Balas  
Tao Ban  
Sang-Woo Ban  
Younès Bennani  
Asim Bhatti  
Janos Botzheim  
Salim Bouzerdoum  
Ivo Bukovsky  
Jinde Cao  
Jiang-Tao Cao  
Chee Seng Chan  
Long Cheng  
Girija Chetty

Andrew Chiou  
Pei-Ling Chiu  
Sung-Bae Cho  
Todsanai Chumwatana  
Pau-Choo Chung  
Jose Alfredo Ferreira Costa  
Justin Dauwels  
Mingcong Deng  
M.L. Dennis Wong  
Hongli Dong  
Hiroshi Dozono  
El-Sayed M. El-Alfy  
Zhouyu Fu  
David Gao  
Tom Gedeon  
Vik Tor Goh  
Nistor Grozavu  
Ping Guo  
Masafumi Hagiwara  
Osman Hassab Elgawi  
Shan He  
Haibo He

Sven Hellbach  
Jer Lang Hong  
Jinglu Hu  
Xiaolin Hu  
Kaizhu Huang  
Amir Hussain  
Kazushi Ikeda  
Piyasak Jeatrakul  
Sungmoon Jeong  
Yaochu Jin  
Zsolt Csaba Johanyák  
Youki Kadobayashi  
Hiroshi Kage  
Joarder Kamruzzaman  
Shin'Ichiro Kanoh  
Nikola Kasabov  
Rhee Man Kil  
Kyung-Joong Kim  
Kyung-Hwan Kim  
Daeun Kim  
Laszlo T. Koczy  
Markus Koskela  
Szilveszter Kovacs  
Naoyuki Kubota  
Takio Kurita  
Olcay Kursun  
James Kwok  
Sungoh Kwon  
Weng Kin Lai  
Siong Hoe Lau  
Yun Li Lee  
Minho Lee  
Nung Kion Lee  
Chin Poo Lee  
Vincent Lemaire  
L. Leng  
Yee Tak Leung  
Bin Li  
Yangming Li  
Ming Li  
Xiaofeng Liao  
Meng-Hui Lim  
C.P. Lim  
Chee Peng Lim  
Kim Chuan Lim

Hsuan-Tien Lin  
Huo Chong Ling  
Derong Liu  
Zhi-Yong Liu  
Chu Kiong Loo  
Wenlian Lu  
Zhiwu Lu  
Bao-Liang Lu  
Shuangge Ma  
Mufti Mahmud  
Kenichiro Miura  
Hiroyuki Nakahara  
Kiyohisa Natsume  
Vinh Nguyen  
Tohru Nitta  
Yusuke Nojima  
Anto Satriyo Nugroho  
Takenori Obo  
Toshiaki Omori  
Takashi Omori  
Thian Song Ong  
Sid-Ali Ouadfeul  
Seiichi Ozawa  
Worapat Paireekreng  
Paul Pang  
Ying Han Pang  
Shaoning Pang  
Hyung-Min Park  
Shri Rai  
Mallipeddi Rammohan  
Alexander Rast  
Jinchang Ren  
Mehdi Roopaei  
Ko Sakai  
Yasuomi Sato  
Naoyuki Sato  
Shunji Satoh  
Manjeevan Seera  
Subana Shanmuganathan  
Bo Shen  
Yang Shi  
Tomohiro Shibata  
Hayaru Shouno  
Jennie Si  
Jungsuk Song

Kingkarn Sookhanaphibarn  
Indra Adji Sulistijono  
Changyin Sun  
Jun Sun  
Masahiro Takatsuka  
Takahiro Takeda  
Shing Chiang Tan  
Syh Yuan Tan  
Ching Seong Tan  
Ken-Ichi Tanaka  
Katsumi Tateno  
Kai Meng Tay  
Connie Tee  
Guo Teng  
Andrew Teoh  
Heizo Tokutaka  
Dat Tran  
Boris Tudjarov  
Eiji Uchino  
Kalyana C. Veluvolu  
Michel Verleysen  
Lipo Wang  
Hongyuan Wang

Frank Wang  
Yin Chai Wang  
Yoshikazu Washizawa  
Kazuho Watanabe  
Bunthit Watanapa  
Kevin Wong  
Kok Seng Wong  
Zenglin Xu  
Yoko Yamaguch  
Koichiro Yamauchi  
Hong Yan  
Wei Qi Yan  
Kun Yang  
Peipei Yang  
Bo Yang  
Xu-Cheng Yin  
Zhigang Zeng  
Min-Ling Zhang  
Chao Zhang  
Rui Zhang  
Yanming Zhang  
Rui Zhang  
Ding-Xuan Zhou



## Table of Contents – Part I

### Cognitive Science

Transfer Entropy and Information Flow Patterns in Functional Brain Networks during Cognitive Activity . . . . .	1
<i>Md. Hedayetul Islam Shovon, D. (Nanda) Nandagopal, Ramasamy Vijayalakshmi, Jia Tina Du, and Bernadine Cocks</i>	
Human Implicit Intent Discrimination Using EEG and Eye Movement . . . . .	11
<i>Ukeob Park, Rammohan Mallipeddi, and Minho Lee</i>	
Towards Establishing Relationships between Human Arousal Level and Motion Mass . . . . .	19
<i>Sven Nõmm, Tiit Kõnnusaar, and Aaro Toomela</i>	
Estimating Nonlinear Spatiotemporal Membrane Dynamics in Active Dendrites . . . . .	27
<i>Toshiaki Omori</i>	
Inter Subject Correlation of Brain Activity during Visuo-Motor Sequence Learning . . . . .	35
<i>Krishna Prasad Miyapuram, Ujjval Pamnani, Kenji Doya, and Raju S. Bapi</i>	
An Agent Response System Based on Mirror Neuron and Theory of Mind . . . . .	42
<i>Kyon-Mo Yang and Sung-Bae Cho</i>	
Dynamic of Nitric Oxide Diffusion in Volume Transmission: Model and Validation . . . . .	50
<i>Fernández López Pablo, García Báez Patricio, and Suárez Araujo Carmen Paz</i>	
A Computational Model of the Relation between Regulation of Negative Emotions and Mood . . . . .	59
<i>Altaf Hussain Abro, Michel C.A. Klein, Adnan R. Manzoor, Seyed Amin Tabatabaei, and Jan Treur</i>	

### Neural Networks and Learning Systems - Theory and Design

Low-Cost Representation for Restricted Boltzmann Machines . . . . .	69
<i>Son N. Tran and Artur d'Avila Garcez</i>	

Add-if-Silent Rule for Training Multi-layered Convolutional Network Neocognitron . . . . .	78
<i>Kunihiko Fukushima</i>	
Posterior Distribution Learning (PDL): A Novel Supervised Learning Framework . . . . .	86
<i>Enmei Tu, Jie Yang, Zhenghong Jia, and Nicola Kasabov</i>	
Computational Model of Neocortical Learning Process: Prototype . . . . .	95
<i>Jing Xian Teo and Henry Lee Seldon</i>	
Active Learning with Maximum Density and Minimum Redundancy . . . . .	103
<i>Yingjie Gu, Zhong Jin, and Steve C. Chiu</i>	
One-to-Many Association Ability of Chaotic Quaternionic Multidirectional Associative Memory . . . . .	111
<i>Takumi Okutsu and Yuko Osana</i>	
An Entropy-Guided Adaptive Co-construction Method of State and Action Spaces in Reinforcement Learning . . . . .	119
<i>Masato Nagayoshi, Hajime Murao, and Hisashi Tamaki</i>	
A Nodes Reduction Procedure for RBFNDDA through Histogram . . . . .	127
<i>Pey Yun Goh, Shing Chiang Tan, and Wooi Ping Cheah</i>	
Toroidal Approximate Identity Neural Networks Are Universal Approximators . . . . .	135
<i>Saeed Panahian Fard and Zarita Zainuddin</i>	
Self-organizing Neural Grove . . . . .	143
<i>Hirotaka Inoue</i>	
Transfer Learning Using the Online FMM Model . . . . .	151
<i>Manjeevan Seera, Chee Peng Lim, and Chu Kiong Loo</i>	
A Supervised Methodology to Measure the Variables Contribution to a Clustering . . . . .	159
<i>Oumaima Alaoui Ismaili, Vincent Lemaire, and Antoine Cornuéjols</i>	
Coupling between Spatial Consistency of Neural Firing and Local Field Potential Coherence: A Computational Study . . . . .	167
<i>Naoyuki Sato</i>	
Fading Channel Prediction Based on Self-optimizing Neural Networks . . . . .	175
<i>Tianben Ding and Akira Hirose</i>	
Invariant Multiparameter Sensitivity of Oscillator Networks . . . . .	183
<i>Kenzaburo Fujiwara, Takuma Tanaka, and Kiyohiko Nakamura</i>	

Spatial-Temporal Saliency Feature Extraction for Robust Mean-Shift Tracker . . . . .	191
<i>Suiwu Zheng, Linshan Liu, and Hong Qiao</i>	
BOOSTRON: Boosting Based Perceptron Learning . . . . .	199
<i>Mirza M. Baig, Mian.M. Awais, and El-Sayed M. El-Alfy</i>	
G-Stream: Growing Neural Gas over Data Stream . . . . .	207
<i>Mohammed Ghesmoune, Hanene Azzag, and Mustapha Lebbah</i>	
Combining Active Learning and Semi-supervised Learning Using Local and Global Consistency . . . . .	215
<i>Yingjie Gu, Zhong Jin, and Steve C. Chiu</i>	
Complex-Valued Neural Networks – Recent Progress and Future Directions (Invited Paper) . . . . .	223
<i>Akira Hirose</i>	
A Cascade System of Simple Dynamic Binary Neural Networks and Its Sparsification . . . . .	231
<i>Jungo Moriyasu and Toshimichi Saito</i>	
A Model of V4 Neurons Based on Sparse Coding . . . . .	239
<i>Hui Wei, Zheng Dong, and Qiang Li</i>	
A Fast and Memory-Efficient Hierarchical Graph Clustering Algorithm . . . . .	247
<i>László Szilágyi, Sándor Miklós Szilágyi, and Béat Hirsbrunner</i>	
Hopfield-Type Associative Memory with Sparse Modular Networks . . . . .	255
<i>Gouhei Tanaka, Toshiyuki Yamane, Daiju Nakano, Ryosho Nakane, and Yasunao Katayama</i>	
Concept Drift Detection Based on Anomaly Analysis . . . . .	263
<i>Anjin Liu, Guangquan Zhang, and Jie Lu</i>	
Online Learning for Faulty RBF Networks with the Concurrent Fault . . . . .	271
<i>Wai Yan Wan, Chi-Sing Leung, Zi-Fa Han, and Ruibin Feng</i>	
The Performance of the Stochastic DNN-kWTA Network . . . . .	279
<i>Ruibin Feng, Chi-Sing Leung, Kai-Tat Ng, and John Sum</i>	
Modularity Maximization Adjusted by Neural Networks . . . . .	287
<i>Desiree Maldonado Carvalho, Hugo Resende, and Mariá C.V. Nascimento</i>	
A Dynamic Pruning Strategy for Incremental Learning on a Budget . . . . .	295
<i>Yusuke Kondo and Koichiro Yamauchi</i>	

Neural Computing with Concurrent Synchrony .....	304
<i>Victor Parque, Masakazu Kobayashi, and Masatake Higashi</i>	
A Line-Partitioned Heteroassociative Memory for Storing Binary Fresnel Hologram .....	312
<i>Peter Wai Ming Tsang and Chi-Sing Leung</i>	
A Unified Framework for Privacy Preserving Data Clustering .....	319
<i>Wenye Li</i>	
Spiking Neural Network with Lateral Inhibition for Reward-Based Associative Learning .....	327
<i>Nooraini Yusoff and Farzana Kabir Ahmad</i>	
Fuzzy Signature Neural Networks for Classification: Optimising the Structure .....	335
<i>Tom Gedeon, Xuanying Zhu, Kun He, and Leana Copeland</i>	
Self-organizing Map-Based Probabilistic Associative Memory .....	342
<i>Yuko Osana</i>	
<b>Neural Networks and Learning Systems - Applications</b>	
A Causal Model for Disease Pathway Discovery .....	350
<i>Ruichu Cai, Chang Yuan, Zhifeng Hao, Wen Wen, Lijuan Wang, Weiqi Chen, and Zhihao Li</i>	
Enhanced Non-linear Features for On-line Handwriting Recognition Using Deep Learning .....	358
<i>Qing Zhang, Minhua Wu, Zhenbo Luo, and Youxin Chen</i>	
Recognizing Human Actions by Using the Evolving Remote Supervised Method of Spiking Neural Networks .....	366
<i>Xiurui Xie, Hong Qu, Guisong Liu, and Lingshuang Liu</i>	
A Neural Networks Committee for the Contextual Bandit Problem .....	374
<i>Robin Allesiardo, Raphaël Féraud, and Djallel Bouneffouf</i>	
Multi-step Predictions of Landslide Displacements Based on Echo State Network .....	382
<i>Wei Yao, Zhigang Zeng, Cheng Lian, Huiming Tang, and Tingwen Huang</i>	
Discrete-Time Nonlinear Generalized Policy Iteration for Optimal Control Using Neural Networks .....	389
<i>Qinglai Wei, Derong Liu, and Xiong Yang</i>	



ANFIS-Based Model for Improved Paraphrase Rating Prediction . . . . .	397
<i>El-Sayed M. El-Alfy</i>	
Contextual Bandit for Active Learning: Active Thompson Sampling . . . .	405
<i>Djallel Bouneffouf, Romain Laroche, Tanguy Urvoy, Raphael Feraud, and Robin Allesiardo</i>	
Choosing the Best Auto-Encoder-Based Bagging Classifier: An Empirical Study . . . . .	413
<i>Yifan Nie, Wenge Rong, Yikang Shen, Chao Li, and Zhang Xiong</i>	
Classification of fMRI Data in the NeuCube Evolving Spiking Neural Network Architecture . . . . .	421
<i>Norhanifah Murlı, Nikola Kasabov, and Bana Handaga</i>	
A Hybrid Approach to Pixel Data Mining . . . . .	429
<i>Subana Shanmuganathan</i>	
A Novel SOH Prediction Framework for the Lithium-ion Battery Using Echo State Network . . . . .	438
<i>Jianmin Wang, Zhe Li, Xiao Li, and Youyi Zhao</i>	
Significance of Non-edge Priors in Gene Regulatory Network Reconstruction . . . . .	446
<i>Ajay Nair, Madhu Chetty, and Pramod P. Wangikar</i>	
Robust Lane Detection Based on Convolutional Neural Network and Random Sample Consensus . . . . .	454
<i>Jihun Kim and Minho Lee</i>	
Learning Local Receptive Fields in Deep Belief Networks for Visual Feature Detection . . . . .	462
<i>Diana Turcsany and Andrzej Bargiela</i>	
Adaptive Wavelet Extreme Learning Machine (AW-ELM) for Index Finger Recognition Using Two-Channel Electromyography . . . . .	471
<i>Khairul Anam and Adel Al-Jumaily</i>	
Text Categorization Using an Automatically Generated Labelled Dataset: An Evaluation Study . . . . .	479
<i>Dengya Zhu and Kok Wai Wong</i>	
Online Recommender System Based on Social Network Regularization . . . . .	487
<i>Zhuo Wang and Hongtao Lu</i>	
A Nonlinear Cross-Site Transfer Learning Approach for Recommender Systems . . . . .	495
<i>Xin Xin, Zhirun Liu, and Heyan Huang</i>	

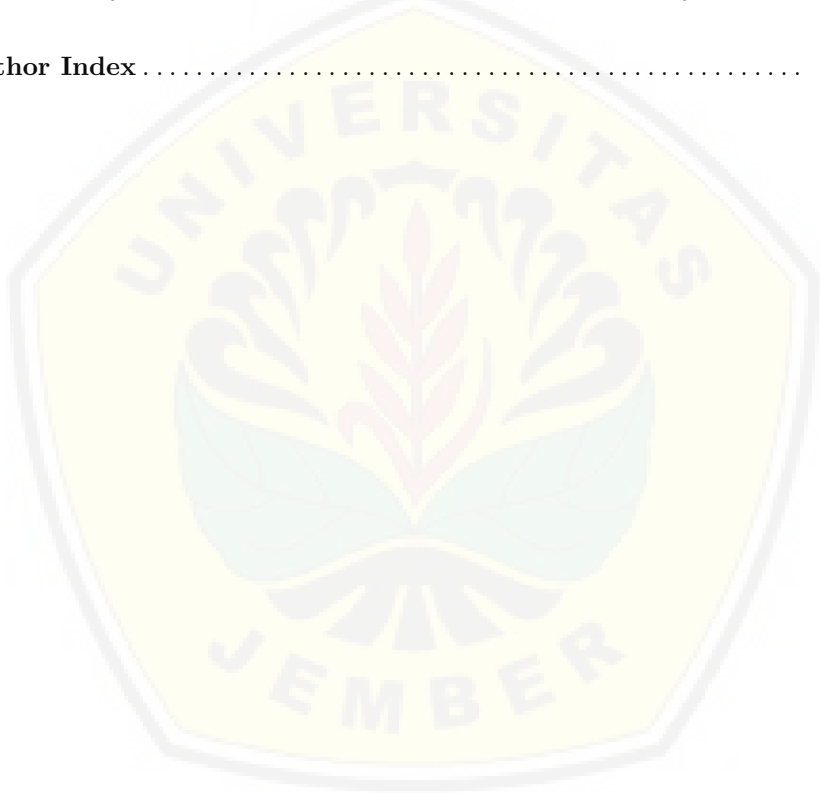
Deep Learning of Multifractal Attributes from Motor Imagery Induced EEG .....	503
<i>Junhua Li and Andrzej Cichocki</i>	
A Fast Neural-Dynamical Approach to Scale-Invariant Object Detection .....	511
<i>Kasim Terzić, David Lobato, Mário Saleiro, and J.M.H. du Buf</i>	
Improving Quantization Quality in Brain-Inspired Self-organization for Non-stationary Data Spaces .....	519
<i>Kasun Gunawardana, Jayantha Rajapakse, and Damminda Alahakoon</i>	
Utilizing High-Dimensional Neural Networks for Pseudo-orthogonalization of Memory Patterns .....	527
<i>Toshifumi Minemoto, Teijiro Isokawa, Haruhiko Nishimura, and Nobuyuki Matsui</i>	
Adaptive Noise Schedule for Denoising Autoencoder .....	535
<i>B. Chandra and Rajesh Kumar Sharma</i>	
Modeling Bi-directional Tree Contexts by Generative Transductions ....	543
<i>Davide Bacciu, Alessio Micheli, and Alessandro Sperduti</i>	
A Novel Architecture for Capturing Discrete Sequences Using Self-organizing Maps .....	551
<i>Manjusri Ishwara, Jayantha Rajapakse, and Damminda Alahakoon</i>	
An Improved Gbest Guided Artificial Bee Colony (IGGABC) Algorithm for Classification and Prediction Tasks .....	559
<i>Habib Shah, Tutut Herawan, Rozaida Ghazali, Rashid Naseem, Maslina Abdul Aziz, and Jemal H. Abawajy</i>	
Artifact Removal from EEG Using a Multi-objective Independent Component Analysis Model .....	570
<i>Sim Kuan Goh, Hussein A. Abbass, Kay Chen Tan, and Abdullah Al Mamun</i>	
Cooperative Feature Level Data Fusion for Authentication Using Neural Networks .....	578
<i>Mark Abernethy and Shri M. Rai</i>	
Fuzzy Output Error as the Performance Function for Training Artificial Neural Networks to Predict Reading Comprehension from Eye Gaze ....	586
<i>Leana Copeland, Tom Gedeon, and Sumudu Mendis</i>	
Part-Based Tracking with Appearance Learning and Structural Constrains .....	594
<i>Wei Xiang and Yue Zhou</i>	

Estimation of Hidden Markov Chains by a Neural Network ..... 602  
*Yoshifusa Ito, Hiroyuki Izumi, and Cidambi Srinivasan*

Corporate Leaders Analytics and Network System (CLANS):  
Constructing and Mining Social Networks among Corporations and  
Business Elites in China ..... 610  
*Yuanyuan Man, Shuai Wang, Tianyu Zhang, T.J. Wong,  
and Irwin King*

Characteristics and Potential Developments of Multiple-MLP Ensemble  
Re-RX Algorithm ..... 619  
*Yoichi Hayashi, Yuki Tanaka, Tomoki Izawa, and Shota Fujisawa*

**Author Index** ..... 629



## Table of Contents – Part II

### Kernel and Statistical Methods

A New Ensemble Clustering Method Based on Dempster-Shafer Evidence Theory and Gaussian Mixture Modeling . . . . .	1
<i>Yi Wu, Xiabi Liu, and Lunhao Guo</i>	
Extraction of Dimension Reduced Features from Empirical Kernel Vector . . . . .	9
<i>Takio Kurita and Yayoi Harashima</i>	
Method of Evolving Non-stationary Multiple Kernel Learning . . . . .	17
<i>Peng Wu, Qian Yin, and Ping Guo</i>	
A Kernel Method to Extract Common Features Based on Mutual Information . . . . .	26
<i>Takamitsu Araki, Hideitsu Hino, and Shotaro Akaho</i>	
Properties of Text-Prompted Multistep Speaker Verification Using Gibbs-Distribution-Based Extended Bayesian Inference for Rejecting Unregistered Speakers . . . . .	35
<i>Shuichi Kurogi, Takuya Ueki, Satoshi Takeguchi, and Yuta Mizobe</i>	
Non-monotonic Feature Selection for Regression . . . . .	44
<i>Haiqin Yang, Zenglin Xu, Irwin King, and Michael R. Lyu</i>	
Non-negative Matrix Factorization with Schatten p-norms Regularization . . . . .	52
<i>Ievgen Redko and Younès Bennani</i>	
A New Energy Model for the Hidden Markov Random Fields . . . . .	60
<i>Jérémie Sublime, Antoine Cornuéjols, and Younès Bennani</i>	
Online Nonlinear Granger Causality Detection by Quantized Kernel Least Mean Square . . . . .	68
<i>Hong Ji, Badong Chen, Zejian Yuan, Nanning Zheng, Andreas Keil, and Jose C. Príncipe</i>	
A Computational Model of Anti-Bayesian Sensory Integration in the Size-Weight Illusion . . . . .	76
<i>Yuki Ueyama</i>	
Unsupervised Dimensionality Reduction for Gaussian Mixture Model . . . . .	84
<i>Xi Yang, Kaizhu Huang, and Rui Zhang</i>	

Graph Kernels Exploiting Weisfeiler-Lehman Graph Isomorphism Test Extensions . . . . .	93
<i>Giovanni Da San Martino, Nicolò Navarin, and Alessandro Sperduti</i>	
Texture Analysis Based Automated Decision Support System for Classification of Skin Cancer Using SA-SVM . . . . .	101
<i>Ammara Masood, Adel Al-Jumaily, and Khairul Anam</i>	
In-attention State Monitoring for a Driver Based on Head Pose and Eye Blinking Detection Using One Class Support Vector Machine . . . . .	110
<i>Hyunrae Jo and Minho Lee</i>	
An Improved Separating Hyperplane Method with Application to Embedded Intelligent Devices . . . . .	118
<i>Yanjun Li, Ping Guo, and Xin Xin</i>	
Fine-Grained Air Quality Monitoring Based on Gaussian Process Regression . . . . .	126
<i>Yun Cheng, Xiucheng Li, Zhijun Li, Shouxu Jiang, and Xiaofan Jiang</i>	
Retrieval of Experiments by Efficient Comparison of Marginal Likelihoods . . . . .	135
<i>Sohan Seth, John Shawe-Taylor, and Samuel Kaski</i>	
 <b>Evolutionary Computation and Hybrid Intelligent Systems</b>	
A New Approach of Diversity Enhanced Particle Swarm Optimization with Neighborhood Search and Adaptive Mutation . . . . .	143
<i>Dang Cong Tran, Zhijian Wu, and Hui Wang</i>	
Data Clustering Based on Particle Swarm Optimization with Neighborhood Search and Cauchy Mutation . . . . .	151
<i>Dang Cong Tran and Zhijian Wu</i>	
Accuracy Improvement of Localization and Mapping of ICP-SLAM via Competitive Associative Nets and Leave-One-Out Cross-Validation . . . . .	160
<i>Shuichi Kurogi, Yoichiro Yamashita, Hikaru Yoshikawa, and Kotaro Hirayama</i>	
Saliency Level Set Evolution . . . . .	170
<i>Jincheng Mei and Bao-Liang Lu</i>	
Application of Cuckoo Search for Design Optimization of Heat Exchangers . . . . .	178
<i>Rihanna Khosravi, Abbas Khosravi, and Saeid Nahavandi</i>	

A Hybrid Method to Improve the Reduction of Ballistocardiogram Artifact from EEG Data . . . . .	186
<i>Ehtasham Javed, Ibrahima Faye, Aamir Saeed Malik, and Jafri Malin Abdullah</i>	
VLGAAC: Variable Length Genetic Algorithm Based Alternative Clustering . . . . .	194
<i>Moumita Saha and Pabitra Mitra</i>	
Social Book Search with Pseudo-Relevance Feedback . . . . .	203
<i>Bin Geng, Fang Zhou, Jiao Qu, Bo-Wen Zhang, Xiao-Ping Cui, and Xu-Cheng Yin</i>	
A Random Key Genetic Algorithm for Live Migration of Multiple Virtual Machines in Data Centers . . . . .	212
<i>Tusher Kumer Sarker and Maolin Tang</i>	
Collaboration of the Radial Basis ART and PSO in Multi-Solution Problems of the Hnon Map . . . . .	221
<i>Fumiaki Tokunaga, Takumi Sato, and Toshimichi Saito</i>	
Reconstructing Gene Regulatory Network with Enhanced Particle Swarm Optimization . . . . .	229
<i>Rezwana Sultana, Dilruba Showkat, Mohammad Samiullah, and Ahsan Raja Chowdhury</i>	
Neural Network Training by Hybrid Accelerated Cuckoo Particle Swarm Optimization Algorithm . . . . .	237
<i>Nazri Mohd Nawawi, Abdullah Khan, M.Z. Rehman, Maslina Abdul Aziz, Tutut Herawan, and Jemal H. Abawajy</i>	
An Accelerated Particle Swarm Optimization Based Levenberg Marquardt Back Propagation Algorithm . . . . .	245
<i>Nazri Mohd Nawawi, Abdullah Khan, M.Z. Rehman, Maslina Abdul Aziz, Tutut Herawan, and Jemal H. Abawajy</i>	
Fission-and-Recombination Particle Swarm Optimizers for Search of Multiple Solutions . . . . .	254
<i>Takumi Sato and Toshimichi Saito</i>	
Fast Generalized Fuzzy C-means Using Particle Swarm Optimization for Image Segmentation . . . . .	263
<i>Dang Cong Tran, Zhijian Wu, and Van Hung Tran</i>	
Evolutionary Learning and Stability of Mixed-Rule Cellular Automata . . . . .	271
<i>Ryo Sawayama and Toshimichi Saito</i>	

## Pattern Recognition Techniques

Radical-Enhanced Chinese Character Embedding . . . . .	279
<i>Yaming Sun, Lei Lin, Nan Yang, Zhenzhou Ji, and Xiaolong Wang</i>	
Conditional Multidimensional Parameter Identification with Asymmetric Correlated Losses of Estimation Errors . . . . .	287
<i>Piotr Kulczycki and Malgorzata Charytanowicz</i>	
Short Text Hashing Improved by Integrating Topic Features and Tags . . . . .	295
<i>Jiaming Xu, Bo Xu, Jun Zhao, Guanhua Tian, Heng Zhang, and Hongwei Hao</i>	
Synthetic Test Data Generation for Hierarchical Graph Clustering Methods . . . . .	303
<i>László Szilágyi, Levente Kovács, and Sándor Miklós Szilágyi</i>	
Optimal Landmark Selection for Nyström Approximation . . . . .	311
<i>Zhouyu Fu</i>	
Privacy Preserving Clustering: A $k$ -Means Type Extension . . . . .	319
<i>Wenye Li</i>	
Stream Quantiles via Maximal Entropy Histograms . . . . .	327
<i>Ognjen Arandjelović, Ducson Pham, and Svetha Venkatesh</i>	
A Unified Framework for Thermal Face Recognition . . . . .	335
<i>Reza Shoja Ghiass, Ognjen Arandjelović, Hakim Bendada, and Xavier Maldague</i>	
Geometric Feature-Based Facial Emotion Recognition Using Two-Stage Fuzzy Reasoning Model . . . . .	344
<i>Md. Nazrul Islam and Chu Kiong Loo</i>	
Human Activity Recognition by Matching Curve Shapes . . . . .	352
<i>Poorna Talkad Sukumar and K. Gopinath</i>	
Sentiment Analysis of Chinese Microblogs Based on Layered Features . . .	361
<i>Dongfang Wang and Fang Li</i>	
Feature Group Weighting and Topological Biclustering . . . . .	369
<i>Tugdual Sarazin, Mustapha Lebbah, Hanane Azzag, and Amine Chaibi</i>	
A Label Completion Approach to Crowd Approximation . . . . .	377
<i>Toshihiro Watanabe and Hisashi Kashima</i>	
Multi-label Linear Discriminant Analysis with Locality Consistency . . .	386
<i>Yuzhang Yuan, Kang Zhao, and Hongtao Lu</i>	

Hashing for Financial Credit Risk Analysis . . . . .	395
<i>Bernardete Ribeiro and Ning Chen</i>	
MAP Inference with MRF by Graduated Non-Convexity and Concavity Procedure . . . . .	404
<i>Zhi-Yong Liu, Hong Qiao, and Jian-Hua Su</i>	
Two-Phase Approach to Link Prediction . . . . .	413
<i>Srinivas Virinchi and Pabitra Mitra</i>	
Properties of Direct Multi-Step Ahead Prediction of Chaotic Time Series and Out-of-Bag Estimate for Model Selection . . . . .	421
<i>Shuichi Kurogi, Ryosuke Shigematsu, and Kohei Ono</i>	
Multi-document Summarization Based on Sentence Clustering . . . . .	429
<i>Hai-Tao Zheng, Shu-Qin Gong, Hao Chen, Yong Jiang, and Shu-Tao Xia</i>	
An Ontology-Based Approach to Query Suggestion Diversification . . . . .	437
<i>Hai-Tao Zheng, Jie Zhao, Yi-Chi Zhang, Yong Jiang, and Shu-Tao Xia</i>	
Sensor Drift Compensation Using Fuzzy Interference System and Sparse-Grid Quadrature Filter in Blood Glucose Control . . . . .	445
<i>Péter Szalay, László Szilágyi, Zoltán Benyó, and Levente Kovács</i>	
Webpage Segmentation Using Ontology and Word Matching . . . . .	454
<i>Huey Jing Toh and Jer Lang Hong</i>	
Continuity of Discrete-Time Fuzzy Systems . . . . .	462
<i>Takashi Mitsuishi, Takanori Terashima, Koji Saigusa, Nami Shimada, Toshimichi Homma, Kiyoshi Sawada, and Yasunari Shidama</i>	
Sib-Based Survival Selection Technique for Protein Structure Prediction in 3D-FCC Lattice Model . . . . .	470
<i>Rumana Nazmul and Madhu Chetty</i>	
Tensor Completion Based on Structural Information . . . . .	479
<i>Zi-Fa Han, Ruibin Feng, Long-Ting Huang, Yi Xiao, Chi-Sing Leung, and Hing Cheung So</i>	
Document Versioning Using Feature Space Distances . . . . .	487
<i>Wei Lee Woon, Kuok-Shoong Daniel Wong, Zeyar Aung, and Davor Svetinovic</i>	



Separation and Classification of Crackles and Bronchial Breath Sounds from Normal Breath Sounds Using Gaussian Mixture Model . . . . .	495
<i>Ali Haider, M. Daniyal Ashraf, M. Usama Azhar, Syed Osama Maruf, Mehdi Naqvi, Sajid Gul Khawaja, and M. Usman Akram</i>	
Combined Features for Face Recognition in Surveillance Conditions . . . . .	503
<i>Khaled Assaleh, Tamer Shanableh, and Kamal Abuqaoud</i>	
Sparse Coding on Multiple Manifold Data . . . . .	515
<i>Hanchao Zhang and Jinhua Xu</i>	
Mutual Information Estimation with Random Forests . . . . .	524
<i>Mike Koeman and Tom Heskes</i>	
Out-Of-Vocabulary Words Recognition Based on Conditional Random Field in Electronic Commerce . . . . .	532
<i>Yanfeng Yang, Yanqin Yang, Hu Guan, and Wenchao Xu</i>	
Least Angle Regression in Orthogonal Case . . . . .	540
<i>Katsuyuki Hagiwara</i>	
Evaluation Protocol of Early Classifiers over Multiple Data Sets . . . . .	548
<i>Asma Dachraoui, Alexis Bondu, and Antoine Cornuéjols</i>	
Exploiting Level-Wise Category Links for Semantic Relatedness Computing . . . . .	556
<i>Hai-Tao Zheng, Wenzhen Wu, Yong Jiang, and Shu-Tao Xia</i>	
Characteristic Prediction of a Varistor in Over-Voltage Protection Application . . . . .	565
<i>Kohei Nagatomo, Muhammad Aziz Muslim, Hiroki Tamura, Koichi Tanno, and Wijono</i>	
Optimizing Complex Building Renovation Process with Fuzzy Signature State Machines . . . . .	573
<i>Gergely I. Molnárka and László T. Kóczy</i>	
News Title Classification with Support from Auxiliary Long Texts . . . . .	581
<i>Yuanxin Ouyang, Yao Huangfu, Hao Sheng, and Zhang Xiong</i>	
Modelling Mediator Intervention in Joint Decision Making Processes Involving Mutual Empathic Understanding . . . . .	589
<i>Rob Duell</i>	
<b>Author Index . . . . .</b>	<b>597</b>

### Signal and Image Processing

Real Time Crowd Counting with Human Detection and Human Tracking . . . . .	1
<i>Xinjian Zhang and Liqing Zhang</i>	
A New Method for Removing Random-Valued Impulse Noise . . . . .	9
<i>Qiyu Jin, Li Bai, Jie Yang, Ion Grama, and Quansheng Liu</i>	
CTR Prediction for DSP with Improved Cube Factorization Model from Historical Bidding Log . . . . .	17
<i>Lili Shan, Lei Lin, Di Shao, and Xiaolong Wang</i>	
Image Retrieval Using a Novel Color Similarity Measurement and Neural Networks . . . . .	25
<i>Cheng Yang and Xiaodong Gu</i>	
Bottom-Up Visual Saliency Using Binary Spectrum of Walsh-Hadamard Transform . . . . .	33
<i>Ying Yu, Jie Lin, and Jian Yang</i>	
Sonification for EEG Frequency Spectrum and EEG-Based Emotion Features . . . . .	42
<i>Yuxi Zhang, Yifeng Huang, Junwei Yue, and Liqing Zhang</i>	
Forecasting Crowd State in Video by an Improved Lattice Boltzmann Model . . . . .	50
<i>Ye Tao, Peng Liu, Wei Zhao, and XiangLong Tang</i>	
Properties of Multiobjective Robust Controller Using Difference Signals and Multiple Competitive Associative Nets in Control of Linear Systems . . . . .	58
<i>Weicheng Huang, Yuki Ishiguma, and Shuichi Kurogi</i>	
Calibrating Independent Component Analysis with Laplacian Reference for Real-Time EEG Artifact Removal . . . . .	68
<i>Hussein A. Abbass</i>	
Unsupervised Segmentation Using Cluster Ensembles . . . . .	76
<i>Wei Zhang, Jie Yang, Wenjing Jia, Nikola Kasabov, Zhenhong Jia, and Lei Zhou</i>	

Similar-Video Retrieval via Learned Exemplars and Time-Warped Alignment . . . . .	85
<i>Teruki Horie, Masafumi Moriwaki, Ryota Yokote, Shota Ninomiya, Akihiro Shikano, and Yasuo Matsuyama</i>	
Automatic Image Annotation Exploiting Textual and Visual Saliency . . .	95
<i>Yun Gu, Haoyang Xue, Jie Yang, and Zhenhong Jia</i>	
Classification of Fish Ectoparasite Genus <i>Gyrodactylus</i> SEM Images Using ASM and Complex Network Model . . . . .	103
<i>Rozniza Ali, Bo Jiang, Mustafa Man, Amir Hussain, and Bin Luo</i>	
Linked Tucker2 Decomposition for Flexible Multi-block Data Analysis . . . . .	111
<i>Tatsuya Yokota and Andrzej Cichocki</i>	
Celebrity Face Image Retrieval Using Multiple Features . . . . .	119
<i>Jie Jin and Liqing Zhang</i>	
A Novel Adaptive Shrinkage Threshold on Shearlet Transform for Image Denoising . . . . .	127
<i>Sheikh Md. Rabiul Islam, Xu Huang, and Kim Le</i>	
Perception of Symmetry in Natural Images: A Cortical Representation of Shape . . . . .	135
<i>Ko Sakai, Ken Kurematsu, and Shouhei Matsuoka</i>	
Image Denoising with Rectified Linear Units . . . . .	142
<i>Yangwei Wu, Haohua Zhao, and Liqing Zhang</i>	
Shape Preserving RGB-D Depth Map Restoration . . . . .	150
<i>Wei Liu, Haoyang Xue, Yun Gu, Jie Yang, Qiang Wu, and Zhenhong Jia</i>	
Online Detection of Concept Drift in Visual Tracking . . . . .	159
<i>Yichen Liu and Yue Zhou</i>	
Temporally Regularized Filters for Common Spatial Patterns by Preserving Locally Linear Structure of EEG Trials . . . . .	167
<i>Minmin Cheng, Haixian Wang, Zuhong Lu, and Deji Lu</i>	
Interactive Color Correction of Display by Dichromatic User . . . . .	175
<i>Hiroki Takagi, Hiroaki Kudo, Tetsuya Matsumoto, Yoshinori Takeuchi, and Noboru Ohnishi</i>	
A Neural Ensemble Approach for Segmentation and Classification of Road Images . . . . .	183
<i>Tejy Kinattukara and Brijesh Verma</i>	

Using Biologically-Inspired Visual Features to Model the Restorative Potential of Scenes . . . . .	194
<i>James Mountstephens</i>	
Classification of Stroke Patients' Motor Imagery EEG with Autoencoders in BCI-FES Rehabilitation Training System . . . . .	202
<i>Mushangshu Chen, Ye Liu, and Liqing Zhang</i>	
Real-Time Patch-Based Tracking with Occlusion Handling . . . . .	210
<i>Jian Tian and Yue Zhou</i>	
Blood Cell Image Retrieval System Using Color, Shape and Bag of Words . . . . .	218
<i>Mohammad Reza Zare and Woo Chaw Seng</i>	
Analysis of OCT Images for Detection of Choroidal Neovascularization in Retinal Pigment Epithelial Layer . . . . .	226
<i>Sadaf Ayaz, Sadaf Sahar, Madeeha Zafar, Muhammad Usman Akram, and Yasser Nadeem</i>	
Online Object Tracking Based on Depth Image with Sparse Coding . . . .	234
<i>Shan-Chun Shen, Wei-Long Zheng, and Bao-Liang Lu</i>	
Real-Time Compressive Tracking with a Particle Filter Framework . . . .	242
<i>Xuan Yao and Yue Zhou</i>	
Image Super-Resolution with Fast Approximate Convolutional Sparse Coding . . . . .	250
<i>Christian Osendorfer, Hubert Soyer, and Patrick van der Smagt</i>	
Sparse Coding for Improved Signal-to-Noise Ratio in MRI . . . . .	258
<i>Fuleah A. Razzaq, Shady Mohamed, Asim Bhatti, and Saeid Nahavandi</i>	
Scalable Video Coding Using Hybrid DCT/Wavelets Architectures . . . .	266
<i>Tamer Shanableh</i>	
Image Enhancement Using Geometric Mean Filter and Gamma Correction for WCE Images . . . . .	276
<i>Shipra Suman, Fawnizu Azmadi Hussin, Aamir Saeed Malik, Nicolas Walter, Khean Lee Goh, Ida Hilmi, and Shiaw hooi Ho</i>	
Autoencoder-Based Collaborative Filtering . . . . .	284
<i>Yuanxin Ouyang, Wenqi Liu, Wenge Rong, and Zhang Xiong</i>	
Extended Laplacian Sparse Coding for Image Categorization . . . . .	292
<i>Mouna Dammak, Mahmoud Mejdoub, and Chokri Ben Amar</i>	

**The 2014 Cybersecurity Data Mining Competition and Workshop (CDMC2014)**

Stochastic Decision Making in Learning Classifier Systems through a Natural Policy Gradient Method ..... 300  
*Gang Chen, Mengjie Zhang, Shaoning Pang, and Colin Douch*

Quantum Inspired Evolutionary Algorithm by Representing Candidate Solution as Normal Distribution ..... 308  
*Sreenivas Sremath Tirumala, Gang Chen, and Shaoning Pang*

Text Categorization with Diversity Random Forests ..... 317  
*Chun Yang, Xu-Cheng Yin, and Kaizhu Huang*

Unknown Attack Detection by Multistage One-Class SVM Focusing on Communication Interval ..... 325  
*Shohei Araki, Yukiko Yamaguchi, Hajime Shimada, and Hiroki Takakura*

Analysis and Configuration of Boundary Difference Calculations ..... 333  
*Simon Dacey, Lei Song, Lei Zhu, and Shaoning Pang*

Morphological Associative Memory Employing a Split Store Method.... 341  
*Hakaru Tamukoh, Kensuke Koga, Hideaki Harada, and Takashi Morie*

A Novel Hybrid Approach for Combining Deep and Traditional Neural Networks ..... 349  
*Rui Zhang, Shufei Zhang, and Kaizhu Huang*

A Classification Method of Darknet Traffic for Advanced Security Monitoring and Response ..... 357  
*Sangjun Ko, Kyuil Kim, Younsu Lee, and Jungsuk Song*

Detecting Malicious Spam Mails: An Online Machine Learning Approach ..... 365  
*Yuli Dai, Shunsuke Tada, Tao Ban, Junji Nakazato, Junpei Shimamura, and Seiichi Ozawa*

**Intelligent Systems for Supporting Decision-Making Processes: Theories and Applications**

Freshness-Aware Thompson Sampling ..... 373  
*Djallel Bouneffouf*

Condition Monitoring of Broken Rotor Bars Using a Hybrid FMM-GA Model ..... 381  
*Manjeevan Seera, Chee Peng Lim, and Chu Kiong Loo*

Employing Genetic Algorithm to Construct Epigenetic Tree-Based Features for Enhancer Region Prediction . . . . .	390
<i>Pui Kwan Fong, Nung Kion Lee, and Mohd Tajuddin Abdullah</i>	
Model and Algorithm for Multi-follower Tri-level Hierarchical Decision-Making . . . . .	398
<i>Jialin Han, Guangquan Zhang, Jie Lu, Yaoguang Hu, and Shuyuan Ma</i>	
A Fuzzy ART-Based Approach for Estimation of High Performance Concrete Mix Proportion . . . . .	407
<i>Fei Ha Chiew, Kok Chin Chai, Chee Khoon Ng, and Kai Meng Tay</i>	
A New Application of an Evolving Tree to Failure Mode and Effect Analysis Methodology . . . . .	415
<i>Wui Lee Chang, Kai Meng Tay, and Chee Peng Lim</i>	
An Application of Fuzzy Adaptive Resonance Theory to Engineering Education . . . . .	423
<i>See Hung Lau, Kai Meng Tay, and Chee Khoon Ng</i>	
Augmented Query Strategies for Active Learning in Stream Data Mining . . . . .	431
<i>Mustafa Amir Faisal, Zeyar Aung, Wei Lee Woon, and Davor Svetinovic</i>	
Feature Selection and Mass Classification Using Particle Swarm Optimization and Support Vector Machine . . . . .	439
<i>Man To Wong, Xiangjian He, Wei-Chang Yeh, Zaidah Ibrahim, and Yuk Ying Chung</i>	
Strategic Decision Support in Waste Management Systems by State Reduction in FCM Models . . . . .	447
<i>Miklós F. Hatwágner, Adrienn Buruzs, Péter Földesi, and László T. Kóczy</i>	
An ELM Based Multi Agent Systems Using Certified Belief in Strength . . . . .	458
<i>Chong Tak Yaw, Keem Siah Yap, Hwa Jen Yap, and Ungku Anisa Ungku Amirulddin</i>	
Constrained-Optimization-Based Bayesian Posterior Probability Extreme Learning Machine for Pattern Classification . . . . .	466
<i>Shen Yuong Wong, Keem Siah Yap, and Hwa Jen Yap</i>	

## Neuroengineering and Neuralcomputing

Adaptive Translational Cueing Motion Algorithm Using Fuzzy Based Tilt Coordination .....	474
<i>Houshyar Asadi, Arash Mohammadi, Shady Mohamed, and Saeid Nahavandi</i>	
Adaptive Washout Algorithm Based Fuzzy Tuning for Improving Human Perception .....	483
<i>Houshyar Asadi, Arash Mohammadi, Shady Mohamed, Delpak Rahim Zadeh, and Saeid Nahavandi</i>	
Neurophysiology of Insects Using Microelectrode Arrays: Current Trends and Future Prospects .....	493
<i>Julie Gaburro, Jean-Bernard Duchemin, Asim Bhatti, Peter Walker, and Saeid Nahavandi</i>	
Neuron’s Spikes Noise Level Classification Using Hidden Markov Models .....	501
<i>Sherif Haggag, Shady Mohamed, Asim Bhatti, Hussein Haggag, and Saeid Nahavandi</i>	
Improved Robust Kalman Filtering for Uncertain Systems with Missing Measurements .....	509
<i>Hossein Rezaei, Shady Mohamed, Reza Mahboobi Esfanjani, and Saeid Nahavandi</i>	
Motor Imagery Data Classification for BCI Application Using Wavelet Packet Feature Extraction .....	519
<i>Imali Thanuja Hettiarachchi, Thanh Thi Nguyen, and Saeid Nahavandi</i>	
Adaptive-Multi-Reference Least Means Squares Filter .....	527
<i>Luke Nyhof, Imali Hettiarachchi, Shady Mohammed, and Saeid Nahavandi</i>	
sEMG-Based Single-Joint Active Training with <i>i</i> Leg—A Horizontal Exoskeleton for Lower Limb Rehabilitation .....	535
<i>Jin Hu, Zeng-Guang Hou, Liang Peng, Long Peng, and Nong Gu</i>	

## Cognitive Robotics

Find Rooms for Improvement: Towards Semi-automatic Labeling of Occupancy Grid Maps .....	543
<i>Sven Hellbach, Marian Himstedt, Frank Bahrmann, Martin Riedel, Thomas Villmann, and Hans-Joachim Böhme</i>	

Understanding Dynamic Environments with Fuzzy Perception . . . . .	553
<i>Frank Bahrmann, Sven Hellbach, Sabrina Keil, and Hans-Joachim Böhme</i>	
Towards Real-World Neurorobotics: Integrated Neuromorphic Visual Attention . . . . .	563
<i>Samantha V. Adams, Alexander D. Rast, Cameron Patterson, Francesco Galluppi, Kevin Brohan, José-Antonio Pérez-Carrasco, Thomas Wennekers, Steve Furber, and Angelo Cangelosi</i>	
On the Role of Working Memory in Trading-Off Skills and Situation Awareness in Sudoku . . . . .	571
<i>George Leu, Jiangjun Tang, and Hussein Abbass</i>	
GA-Tetris Bot: Evolving a Better Tetris Gameplay Using Adaptive Evaluation Scheme . . . . .	579
<i>Somnuk Phon-Amnuaisuk</i>	
An Effectiveness of Model-Based Development with User Model in Consideration of Human . . . . .	587
<i>Yoshinobu Akimoto, Eri Sato-Shimokawara, Yasunari Fujimoto, and Toru Yamaguchi</i>	
Dynamic Programming for Guided Gene Transfer in Bacterial Memetic Algorithm . . . . .	596
<i>Tiong Yew Tang, Simon Egerton, János Botzheim, and Naoyuki Kubota</i>	
Topological Gaussian Adaptive Resonance Associative Memory with Fuzzy Motion Planning for Place Navigation . . . . .	604
<i>Wei Hong Chin and Chu Kiong Loo</i>	
<b>Security in Signal Processing and Machine Learning</b>	
Anomaly Based Intrusion Detection through Temporal Classification . . .	612
<i>Shih Yin Ooi, Shing Chiang Tan, and Wooi Ping Cheah</i>	
Threshold Visual Secret Sharing Based on Boolean Operations and Random Grids . . . . .	620
<i>Xuehu Yan, Shen Wang, and Xiamu Niu</i>	
Wavelet Based SDA for Face Recognition . . . . .	628
<i>Goh Fan Ling, Pang Ying Han, Liew Yee Ping, Ooi Shih Yin, and Loo Chu Kiong</i>	
Essential Visual Cryptographic Scheme with Different Importance of Shares . . . . .	636
<i>Xuehu Yan, Shen Wang, Xiamu Niu, and Ching-Nung Yang</i>	



Improved Biohashing Method Based on Most Intensive Histogram  
Block Location ..... 644  
*Munalih Ahmad Syarif, Thian Song Ong, Andrew Beng Jin Teoh,  
and Connie Tee*

2.5D Face Recognition under Tensor Manifold Metrics ..... 653  
*Lee-Ying Chong, Andrew Beng Jin Teoh, Thian-Song Ong,  
and Siew-Chin Chong*

**Learning Systems for Social Network and Web Mining**

Predicting Mobile Subscriber’s Behaviour from Contextual Information  
Extraction: SMS Data ..... 661  
*Ayesha Javed Butt, Naveed Anwer Butt, Rabia Ghias Butt,  
and Muhammad Touseef Ikram*

Discovering Plain-Text-Described Services Based on Ontology  
Learning ..... 673  
*Hai Dong, Farookh Khadeer Hussain, and Athman Bouguettaya*

A Fuzzy VSM-Based Approach for Semantic Service Retrieval ..... 682  
*Supannada Chotipant, Farookh Khadeer Hussain, Hai Dong,  
and Omar Khadeer Hussain*

Maintaining Trust in Cloud Computing through SLA Monitoring ..... 690  
*Walayat Hussain, Farookh Khadeer Hussain,  
and Omar Khadeer Hussain*

**Author Index** ..... 699

# Adaptive Wavelet Extreme Learning Machine (AW-ELM) for Index Finger Recognition Using Two-Channel Electromyography

Khairul Anam<sup>1,2</sup> and Adel Al-Jumaily<sup>2</sup>

<sup>1</sup>University of Jember, Indonesia

Khairul.Anam@student.uts.edu.au

<sup>2</sup>University of Technology Sydney, Australia

adel@uts.edu.au

**Abstract.** This paper proposes a new structure of wavelet extreme learning machine i.e. an adaptive wavelet extreme learning machine (AW-ELM) for finger motion recognition using only two EMG channels. The adaptation mechanism is performed by adjusting the wavelet shape based on the input information. The performance of the proposed method is compared to ELM using wavelet (W-ELM0 and sigmoid (Sig-ELM) activation function. The experimental results demonstrate that the proposed AW-ELM performs better than W-ELM and Sig-ELM.

**Keywords:** Wavelet extreme learning machine, adaptive.

## 1 Introduction

A wavelet neural network (WNN) is a special case of a feed-forward neural network which its activation function is wavelets [1]. A standard gradient descend can be used to train the weight of WNN. However, drawbacks of the gradient descent method such as long training time and easy trapped to local minima have hampered the implementation of WNN in the real-time application [2]. On the other hand, an extreme learning machine (ELM) was introduced to train a single-hidden layer feed-forward networks (SLFNs) resulting in a system which is fast and able to avoid a local minima [3]. Inevitably, WNN can be constructed using SLFNs.

The combination of ELM and WNN can be conducted by simply replacing the activation function of ELM with wavelets [4] [5]. This is the simplest unification of both networks as has been done in [5]. Cao et al. [6] introduced a new combination of these two algorithms by proposing a composite function of WNN with ELM. In this method, they implemented two activation functions, a wavelet function and any piecewise function which are done in order.

Another new unification of ELM and WNN was proposed by Javed et al. [7] who proposed a summation wavelet extreme learning machine (SW-ELM). Same as Cao, Javed et al. utilized two activation functions but employed them in different ways.

These two activation functions were done in parallel and their outputs were averaged to be the output of the hidden nodes.

This paper proposes an adaptive wavelet extreme learning machine (AW-ELM), a new unification of ELM and WNN. According to WNN structure, the proposed system utilizes a wavelet function as the activation function in the hidden node. However, the activation functions are not fixed but they are adjusted regarding to the changing in the input. The sigmoid function is used to process the input information and produce translation parameters of the wavelets in the related hidden-node. In this paper, the performance of AW-ELM will be tested to classify the finger motions from the surface Electromyography signal (EMG) extracted from two-channel sources on the forearm. In addition, its classification performance will be compared with two types of ELM, ELM with wavelet activation function (W-ELM) and sigmoid activation function (Sig-ELM).

The organization of the paper is as follows: section 2 describes the theory of W-ELM and AW-ELM, and the implementation of AW-ELM for finger motion classification. Then section 3 and 4 presents the results and the discussion. Finally section 4 will conclude this paper.

## 2 Methods

### 2.1 Wavelet Extreme Learning Machine (W-ELM)

W-ELM can be considered as a special case of extreme learning machine which its activation function is wavelets. The output function of W-ELM for arbitrary samples  $(\mathbf{x}_k, t_k) \in \mathbf{R}^n \times \mathbf{R}^o$  with M hidden nodes is

$$f_i^k(\mathbf{x}) = \sum_{j=1}^M V_{ij} \psi_{a_j b_j}(w_j, c_j, \mathbf{x}_k) \quad i = 1, 2, \dots, O \quad (1)$$

where

$$\psi_{a_j b_j}(x) = \frac{1}{\sqrt{a_j}} \psi\left(\frac{x - b_j}{a_j}\right), \quad j = 1, 2, \dots, M \quad (2)$$

in which  $a_j$  and  $b_j$  are dilatation and translation parameters of the wavelets, respectively. An initialization of dilatation and translation parameters,  $a_j$  and  $b_j$ , in WNN is an important issue. The initialization should consider the input information in order to let the time domain of the wavelet covering the input domain. According to [1], suppose the input vector  $x_k$  has the domain  $[x_{kmin}, x_{kmax}]$ ,  $t^*$  and  $\sigma^*$  are the centre and the radius of the mother wavelet  $\psi_{a_i b_i}$ , then domain of  $\psi_{a_i b_i}$  is given by:

$$[b_j + a_j(t^* - \sigma^*), b_j + a_j(t^* + \sigma^*)]$$

Meanwhile, the input information range for  $i$ th hidden layer can be calculated as:

$$\left[ \sum_{i=1}^N w_{ji} x_{i \min} , \sum_{i=1}^N w_{ji} x_{i \max} \right]$$

where  $w_{ji}$  is the weight connecting the  $j$ th hidden layer the  $i$ th input. The wavelet can cover the input space if

$$b_j + a_j (t^* - \sigma^*) = \sum_{i=1}^N w_{ji} x_{i \min} \tag{3}$$

and

$$b_j + a_j (t^* + \sigma^*) = \sum_{i=1}^N w_{ji} x_{i \max} \tag{4}$$

From equation (9) and (10), we can calculate  $a_i$  and  $b_i$  as:

$$a_j = \frac{1}{2\sigma^*} \left( \sum_{i=1}^N w_{ji} x_{i \max} - \sum_{i=1}^N w_{ji} x_{i \min} \right) \tag{5}$$

$$b_j = \frac{1}{2\sigma^*} \left( \sum_{i=1}^N w_{ji} x_{i \max} (\sigma^* - t^*) + \sum_{i=1}^N w_{ji} x_{i \min} (\sigma^* + t^*) \right) \tag{6}$$

## 2.2 Adaptive Wavelet Extreme Learning Machine (AW-ELM)

### The Proposed Structure

The proposed AW-ELM is depicted by Fig. 1. If  $M$  is the number of hidden node and  $N$  is the number of input, then the input of the hidden layer  $P_j$  is given by

$$P_j(x) = \sum_{i=1}^N x_i w_{ji} + c_j \quad j = 1, 2, \dots, M \tag{7}$$

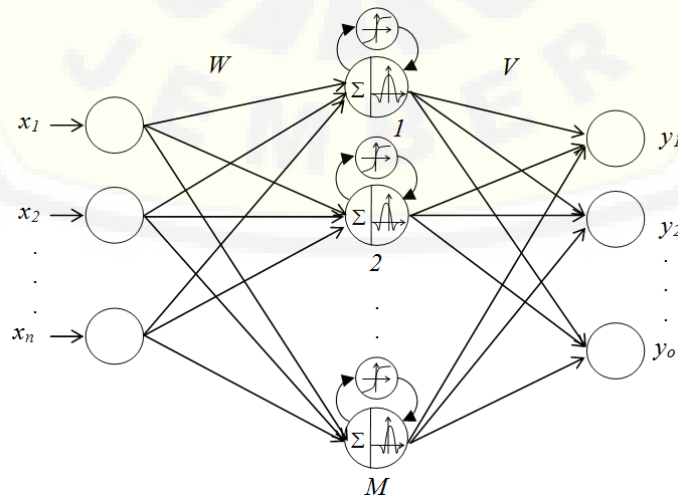


Fig. 1. The proposed adaptive wavelet extreme learning machine

where  $x_i$  are the input variables,  $w_{ji}$  are the weights of the connection between  $i$ th input and  $j$ th hidden nodes, and  $c_j$  denotes the bias of  $j$ th hidden layer. Using equation (8), the output of the hidden node is given by:

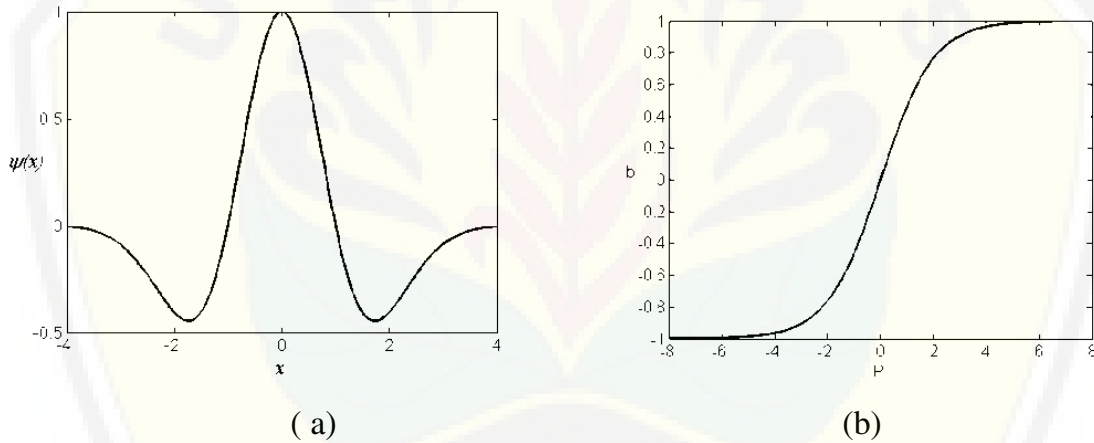
$$\psi_{a_j b_j}(P_j(x)) = \psi\left(\frac{P_j(x) - b_j}{a_j}\right), \quad j = 1, 2, \dots, M \quad (8)$$

In this proposed work, the Mexican Hat function [6] is used as the mother wavelet  $\psi_{a_j b_j}$  as described in fig. 2a, and defined as

$$\psi(x) = e^{-x^2/2}(1 - x^2) \quad (9)$$

Therefore, the wavelet activation function of AW-ELM is:

$$\psi_{a_j b_j}(P_j) = e^{-0.5\left(\frac{P_j - b_j}{a_j}\right)^2} \left(1 - \left(\frac{P_j - b_j}{a_j}\right)^2\right) \quad (10)$$



**Fig. 2.** Two difference functions used in this work: (a) The mother wavelet of the Mexican hat (b) A nonlinear function to produce  $b_j$

In this proposed AW-ELM, the dilatation parameters  $a_j$  are fixed and initialized using Equation (5). As for the translation parameters  $b_j$ , they are varied according to the input information and driven by a nonlinear function  $f(\cdot)$  as follows:

$$b_j = f(P_j) \quad (11)$$

where

$$f(P_j) = \frac{2}{1 + e^{-P_j}} - 1 \quad (12)$$

as depicted in Fig. 2b. Eventually, a new structure of an adaptive W-ELM is presented in Fig. 1. A small circle on the top of each hidden node is used to adjust the b parameters in order to change the shape of the wavelet. Thus, the output of AW-ELM is:

$$f_i^k(\mathbf{x}) = \sum_{j=1}^M V_{ij} \psi_{a_j b_j}(w_j, c_j, \mathbf{x}_k) = \sum_{j=1}^M V_{ij} \psi_{a_j b_j}(P_j(\mathbf{x}_k)) \quad i = 1, 2, \dots, O \quad (13)$$

### The Learning Algorithm

For the desired output:

$$D = (\mathbf{d}_1^T \quad \mathbf{d}_2^T \quad \dots \quad \mathbf{d}_L^T)_{L \times O} \quad (14)$$

The AW-ELM described in (13) can be written as a linear system as follows:

$$H\mathbf{V} = D \quad (15)$$

where

$$H = \begin{bmatrix} \psi_{a_1 b_1}(P_1(\mathbf{x}_1)) & \dots & \psi_{a_M b_M}(P_M(\mathbf{x}_1)) \\ \vdots & \vdots & \vdots \\ \psi_{a_1 b_1}(P_1(\mathbf{x}_L)) & \vdots & \psi_{a_M b_M}(P_M(\mathbf{x}_L)) \end{bmatrix}_{L \times M} \quad (16)$$

$$\mathbf{V} = (\mathbf{v}_1^T \quad \mathbf{v}_2^T \quad \dots \quad \mathbf{v}_O^T)_{M \times O}^T \quad (17)$$

V can be obtained by solving the least-square solution of (15) and given by:

$$\hat{\mathbf{V}} = H^\dagger D \quad (18)$$

where  $H^\dagger$  is the Moore-Penrose generalized inverse of the matrix H.

The training algorithm of AW-ELM can be implemented as follows:

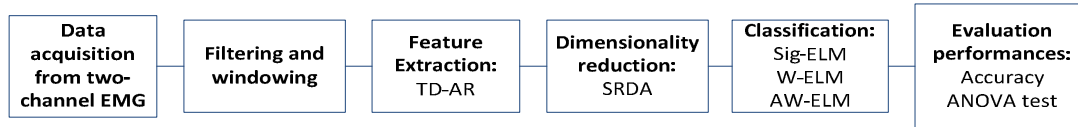
**Algorithm of AW-ELM.** Given a training set  $\mathfrak{X} = \{(\mathbf{x}_k, t_k) \mid \mathbf{x}_k \in \mathbf{R}^n, t_k \in \mathbf{R}^o, k = 1, 2, \dots, L\}$ , the hidden node output function  $\psi_{a_i, b_i}(w, c; \mathbf{x})$  and the hidden node number  $M$ :

- (1) Randomly assign vector matrix W and initialize the hidden node parameters  $a_j, j = 1, 2, \dots, M$  according to (5)
- (2) Calculate the input hidden layer  $P_j$  in (7)
- (3) Calculate  $\underline{b}_j$  in (11) and (12)
- (4) Calculate the hidden layer output H in (16)
- (5) Calculate the output weight  $\hat{\mathbf{V}}$  in (18)

### 2.3 AW-ELM for Finger Motion Recognition

The proposed recognition system consists of the same stages as depicted in Figure 3. Firstly, signals from two-channel EMG located on the forearm were acquired by a

data acquisition device from eight subjects. The experimental procedures for the data acquisition could be referred to [8]. Then the filtering and windowing was applied to the collected data before being extracted using a time domain (TD) and autoregressive (AR) features.



**Fig. 2.** The motion finger classification using AW-ELM

The features were extracted from the time domain feature set which consists of Waveform Length (WL), Slope Sign Changes (SSC), Number of Zero Crossings (ZCC), and Sample Skewness (SS). In addition, some parameters from Hjorth Time Domain Parameters (HTD) and Auto Regressive (AR) Model Parameters were included. To reduce the dimension of the features, SDRA was employed. All features were concatenated and reduced using SRDA. SRDA is an extension of LDA that can deal with singularity and a large data set. The 200 ms window length was applied to the signal to comply with the real time application along with a 25 increment.

The reduced feature set resulted in the previous stage is utilized in the classification. The objective of the classification that was performed using AW-ELM and other ELM classifiers is to recognize ten classes of the individual and combined finger movements consisting of the flexion of individuated fingers. They consisted of Thumb (T), Index (I), Middle (M), Ring (R), Little (L) and the pinching of combined Thumb–Index (T–I), Thumb–Middle (T–M), Thumb–Ring (T–R), Thumb–Little (T–L), and the hand close (HC). Finally, statistical analyses were performed to validate the result.

### 3 Results and Discussion

In this section, the performance of the proposed AW-ELM was compared to wavelet extreme learning machine (W-ELM) and sigmoid extreme learning machine (sig-ELM). All classifiers classified ten finger motions using EMG signal from two channel electrodes. The four-fold cross validation was used to validate the classification results. Simulation was done in the MATLAB 8.3 environment running on 2.8 GHz PC.

Table 1 shows the classification results of three classifiers in recognizing ten finger motions classes defined in 2.4. In all ELMs, the number of hidden nodes varied from 50 up to 500. The results indicate that the average accuracy the proposed of AW-ELM was higher than standard W-ELM in all cases. Likewise, the AW-ELM performance is better than Sig-ELM in all hidden node numbers except 50 and 75. In these two hidden numbers, the Sig-Elm achieved better accuracy that AW-ELM. Overall, the adaptation of wavelet shape using a sigmoid function in AW-ELM could enhance the performance of the original wavelet extreme learning machine and in several condition, could attain better performance than Sig-ELM.

**Table 1.** The average classification accuracy of AW-ELM across eight subjects using four-fold cross validation compared with W-ELM and Sig-ELM

# Hidden Node	Accuracy (%)		
	W-ELM	AW-ELM	Sig-ELM
50	91.07 ± 0.17	91.57 ± 0.08	<b>91.65 ± 0.08</b>
75	91.56 ± 0.14	91.93 ± 0.14	<b>91.97 ± 0.10</b>
100	91.79 ± 0.10	<b>92.05 ± 0.09</b>	92.01 ± 0.08
125	91.90 ± 0.08	<b>92.08 ± 0.09</b>	92.03 ± 0.10
150	91.94 ± 0.11	<b>92.06 ± 0.10</b>	92.04 ± 0.10
175	91.98 ± 0.09	<b>92.06 ± 0.09</b>	92.04 ± 0.08
200	91.99 ± 0.08	<b>92.04 ± 0.08</b>	92.01 ± 0.06
500	91.79 ± 0.08	<b>91.56 ± 0.06</b>	91.37 ± 0.06

**Table 2.** Processing time of different ELM classifiers

#Hidden Node	Training Time (s)			Testing Time (s)		
	W-ELM	AW-ELM	Sig-ELM	W-ELM	AW-ELM	Sig-ELM
50	0.16 ± 0.01	0.19 ± 0.02	0.12 ± 0.00	0.03 ± 0.00	0.06 ± 0.00	0.01 ± 0.00
75	0.28 ± 0.01	0.33 ± 0.01	0.19 ± 0.00	0.06 ± 0.01	0.07 ± 0.00	0.02 ± 0.00
100	0.38 ± 0.02	0.45 ± 0.02	0.27 ± 0.01	0.07 ± 0.00	0.10 ± 0.00	0.02 ± 0.00
125	0.59 ± 0.05	0.70 ± 0.06	0.48 ± 0.07	0.09 ± 0.00	0.14 ± 0.00	0.03 ± 0.00
150	0.71 ± 0.01	0.81 ± 0.01	0.51 ± 0.01	0.12 ± 0.00	0.19 ± 0.01	0.04 ± 0.00
175	0.93 ± 0.06	1.06 ± 0.05	0.69 ± 0.05	0.14 ± 0.00	0.22 ± 0.00	0.04 ± 0.00
200	1.07 ± 0.08	1.22 ± 0.05	0.85 ± 0.06	0.17 ± 0.00	0.26 ± 0.00	0.05 ± 0.00
500	4.20 ± 0.08	5.42 ± 0.08	2.82 ± 0.10	0.75 ± 0.01	1.28 ± 0.01	0.12 ± 0.00

In terms of processing time, the ELM using a sigmoid function (Sig-ELM) spent less training time than W-ELM and AW-ELM in as shown in Table 2. Table 2 shows that the larger the number of the hidden node, the longer the time difference between AW-ELM and Sig-ELM. Likewise, in the testing time, AW-ELM is the slowest system. The adaptive mechanism adds the processing time in both the training and testing trials.

**Table 3.** The p-value of anova test on the classification accuracy between AW-ELM and other tested classifiers

#Hidden Node	p-value	
	AW-ELM & W-ELM	AW-ELM & Sig-ELM
50	<b>0.0000</b>	<b>0.0000</b>
75	<b>0.0000</b>	0.1283
100	<b>0.0000</b>	<b>0.0006</b>
125	<b>0.0000</b>	0.0610
150	<b>0.0000</b>	0.3477
175	<b>0.0021</b>	0.5746
200	<b>0.0098</b>	0.0552
500	<b>0.0000</b>	<b>0.0000</b>



The one-way ANOVA test was done to evaluate the improvement significance of AW-ELM compared to W-ELM and Sig-ELM as presented in Table 4. Table 4 shows that p-values on the comparison of AW-ELM and W-ELM are less than 0.05. In other words, the performance improvement in recognizing ten finger motions by AW-ELM is significantly achieved. Furthermore, the performance of AW-ELM and Sig-ELM in some cases is significantly different in the hidden number node 50, 100 and 500 whereas it is significantly similar in other hidden node numbers. Nevertheless, the AW-ELM produced better accuracy in most trials than Sig-ELM.

## 4 Conclusion

This paper proposed a novel ELM i.e. an adaptive wavelet extreme learning (AW-ELM) for recognizing finger motions using two-channel EMG signals. The adaptation mechanism of the proposed method is conducted by adjusting the shape of the wavelet based on the information provided in the input. The experimental results showed that the proposed AW-ELM improved the performance of the original wavelet ELM in all cases tested and performed better than Sig-ELM in most cases observed. In the future, the performance of AW-ELM should be compared with other well-known classifiers such as support vector machine (SVM) and Linear Discriminant Analysis (LDA).

## References

1. Zhou, B., Shi, A., Cai, F., Zhang, Y.-S.: Wavelet neural networks for nonlinear time series analysis. In: Yin, F.-L., Wang, J., Guo, C. (eds.) ISNN 2004. LNCS, vol. 3174, pp. 430–435. Springer, Heidelberg (2004)
2. Lin, C.-J., Tsai, H.-M.: FPGA implementation of a wavelet neural network with particle swarm optimization learning. *Mathematical and Computer Modelling* 47(9-10), 982–996 (2008)
3. Huang, G.B., et al.: Extreme learning machine for regression and multiclass classification. *IEEE Trans. Syst. Man Cybern. B, Cybern.* 42(2), 513–529 (2012)
4. Cao, J., Lin, Z., Huang, G.-B.: Composite function wavelet neural networks with extreme learning machine. *Neurocomputing* 73(7), 1405–1416 (2010)
5. Salih, D.M., et al.: Wavelet network based online sequential extreme learning machine for dynamic system modeling. In: 2013 9th Asian Control Conference (ASCC) (2013)
6. Ling, S.-H., et al.: Improved hybrid particle swarm optimized wavelet neural network for modeling the development of fluid dispensing for electronic packaging. *IEEE Transactions on Industrial Electronics* 55(9), 3447–3460 (2008)
7. Javed, K., Gouriveau, R., Zerhouni, N.: SW-ELM: A summation wavelet extreme learning machine algorithm with a priori parameter initialization. *Neurocomputing* 123, 299–307 (2014)
8. Anam, K., Al-Jumaily, A.A.: Swarm-based extreme learning machine for finger movement recognition. In: 2014 Middle East Conference on Biomedical Engineering (MECBME) (2014)