MAKALAH ILMIAH
JURNAL INTERNASIONAL BEREPUTASI

Neural Networks
Vol. 85, January 2017

Indexing	**:**	**Scopus, ISI Web of Science dll**
Quartile	**:**	**Q1 in Artificial Intelligence**
H-indeks	**:**	**108**
Impact Factor	**:**	**5,287**
ISSN	**:**	**08936080**

Judul:

Evaluation of Extreme Learning Machine for Classification of Individual and Combined Finger Movements Using Electromyography on Amputees and Non-Amputees

disusun oleh:

Khairul Anam dkk

JURUSAN TEKNIK ELEKTRO
FAKULTAS TEKNIK
UNIVERSITAS JEMBER
2017

Volume 85, January 2017 ISSN 0893-6080

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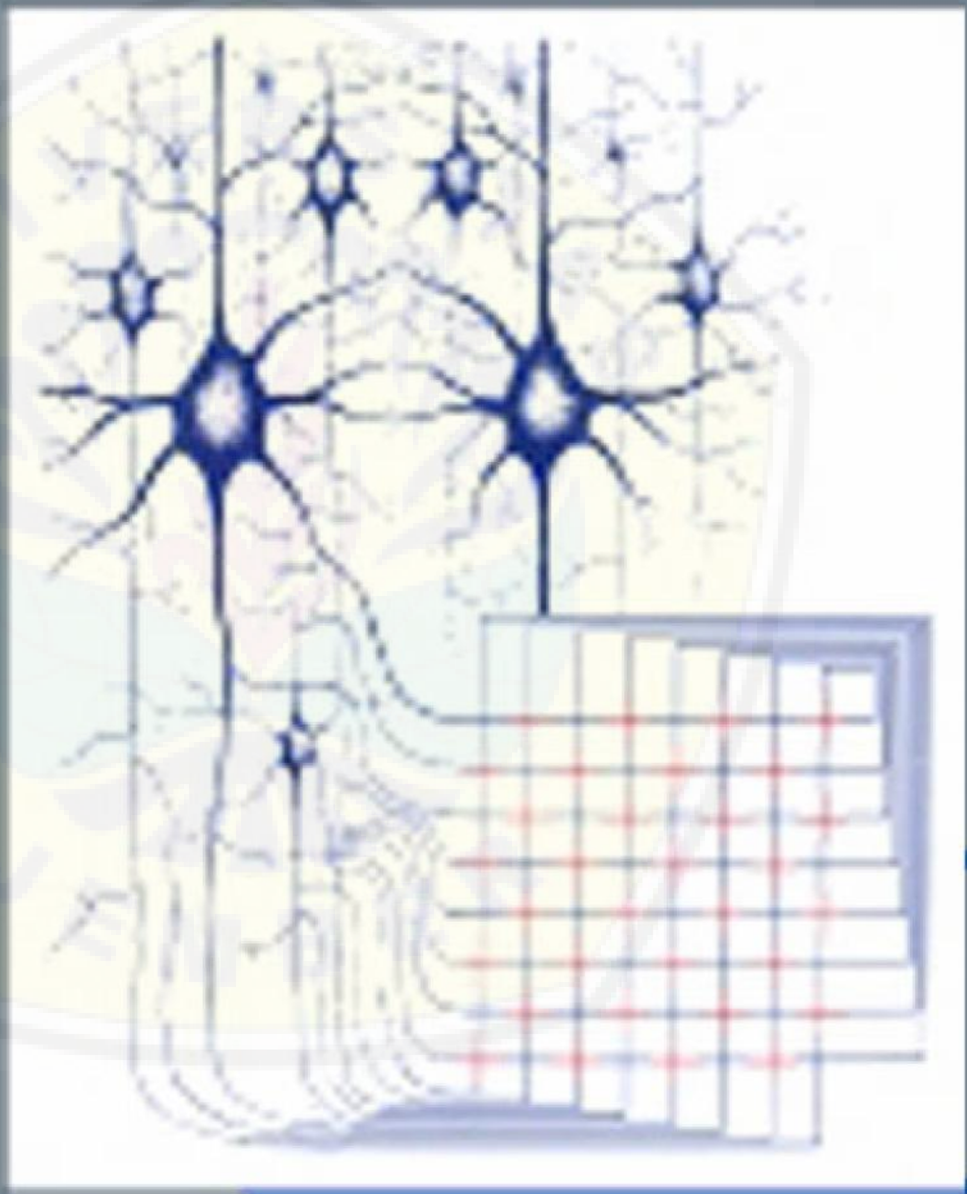

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Editorial Offices: Kenji Doya, Okinawa Institute of Science and Technology, Neural Computation Unit, 1919-1 Tancha, Onna, Okinawa, 904-0495, Japan; DeLiang Wang, Department of Computer Science and Engineering, 2015 Neil Avenue, The Ohio State University, Columbus, OH 43210-1277, USA.

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Publication information: *Neural Networks* (ISSN 0893-6080). For 2017, volumes 85–96 (12 issues) are scheduled for publication. Subscription prices are available upon request from the Publisher or from the Elsevier Customer Service Department nearest you or from this journal's website (http://www.elsevier.com/locate/neunet). Further information is available on this journal and other Elsevier products through Elsevier's website: (http://www.elsevier.com). Subscriptions are accepted on a prepaid basis only and are entered on a calendar year basis. Issues are sent by standard mail (surface within Europe, air delivery outside Europe). Priority rates are available upon request. Claims for missing issues should be made within six months of the date of dispatch.

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Neural Networks 85 (2017) v–ix

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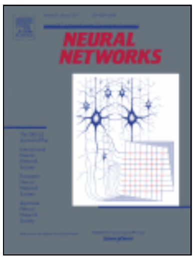

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Highlights

- Effects of a shortcut on rotating waves in a ring of sigmoidal neurons are considered.
- A kinematical equation for the propagation of wave fronts in a rotating wave is derived.
- Rotating waves can be stabilized in the presence of an inhibitory shortcut.
- Dynamical metastability of rotating waves is lost in the presence of an excitatory shortcut.

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Contents lists available at ScienceDirect

Neural Networks

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Evaluation of extreme learning machine for classification of individual and combined finger movements using electromyography on amputees and non-amputees

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ARTICLE INFO

Article history:
Received 17 January 2016
Received in revised form 17 July 2016
Accepted 7 September 2016
Available online 1 October 2016

Keywords:
Classification
Myoelectric pattern recognition
Electromyography (EMG)
Extreme learning machine (ELM)
Amputee

ABSTRACT

The success of myoelectric pattern recognition (M-PR) mostly relies on the features extracted and classifier employed. This paper proposes and evaluates a fast classifier, extreme learning machine (ELM), to classify individual and combined finger movements on amputees and non-amputees. ELM is a single hidden layer feed-forward network (SLFN) that avoids iterative learning by determining input weights randomly and output weights analytically. Therefore, it can accelerate the training time of SLFNs. In addition to the classifier evaluation, this paper evaluates various feature combinations to improve the performance of M-PR and investigate some feature projections to improve the class separability of the features. Different from other studies on the implementation of ELM in the myoelectric controller, this paper presents a complete and thorough investigation of various types of ELMs including the node-based and kernel-based ELM. Furthermore, this paper provides comparisons of ELMs and other well-known classifiers such as linear discriminant analysis (LDA), k-nearest neighbour (kNN), support vector machine (SVM) and least-square SVM (LS-SVM). The experimental results show the most accurate ELM classifier is radial basis function ELM (RBF-ELM). The comparison of RBF-ELM and other well-known classifiers shows that RBF-ELM is as accurate as SVM and LS-SVM but faster than the SVM family; it is superior to LDA and kNN. The experimental results also indicate that the accuracy gap of the M-PR on the amputees and non-amputees is not too much with the accuracy of 98.55% on amputees and 99.5% on the non-amputees using six electromyography (EMG) channels.

1. Introduction

A hand disability is one of the most frequent disability problems that occur in the community. The hand disability can be caused by either amputation or a motor function problem. The development of the perfect technology for hand rehabilitation is a challenging task. Various cutting-edge technologies have been developed to deal with the hand rehabilitation. For hand amputees, Touch Bionics Limited has introduced a revolutionary prosthetic hand named iLimb (TouchBionics, 2007). The iLimb looks like a natural hand, and it is designed in such a way that it conforms around the shape of an object being grasped. I-LIMB has five fingers so that it can perform a large number of finger configurations. Another example of a bionic hand that is available in the market is a bebionic hand by RSLSteeper (Scheme & Englehart, 2011). Thus, the hardware of the robotic hands that mimic the hand in the shape and functionality is available. These sophisticated prosthetic hands need a sophisticated control system that can be applied in the real-time application. In addition, the control system should work in agreement with a human's desire to enhance the convenience of the wearer. A so-called myoelectric control system (MCS) which utilized a pattern-recognition method can be employed to meet the demands of the control system on the dexterous prosthetic hand (Oskoei & Hu, 2007).

Feed-forward neural networks (FFNNs) or multi-layer perceptron (MLP) have become a popular classifier in the field of myoelectric pattern recognition system (M-PR). To the best of the authors' knowledge, Uchida, Hiraiwa, Sonehara, and Shimohara (1992) were the first researchers implementing FFNNs on the M-PR for finger movement classification. In the proposed system, FFNNs

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http://dx.doi.org/10.1016/j.neunet.2016.09.004
0893-6080/