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Extreme Learning Machines: A Primer

Matthew N. O. Sadiku, PhD, PE,[1], Justin Foreman, PhD[2], Sarhan Musa, PhD, PE[3]
1,2 Departement of Electrical and Computer Engineering
3 College of Engineering
Prairie View A&M University, Prairie View, TX, USA
mnsadiku@pvamu.edu

Abstract : Extreme learning machine (ELM) is an emerging machine learning algorithm possessing a single hidden layer forward neural network with an extremely low computational cost. The traditional learning methods (such as support vector machine, neural networks and manifold learning) often require large amounts of time to train the models and to classify new data. ELM is based on the single-hidden feed-forward networks, which randomly select input weights and analytically determine the output weights. It is widely implemented due to its simplified algorithm, reduced computational costs, and ease of implementation. This paper provides a brief and simple introduction to ELM, its applications and challenges. It will be useful for researchers who are new in this field.
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Keywords: extreme learning machines, neural networks

I. Introduction

Machine learning deals with the construction of systems that can learn from data. Traditional machine learning techniques (such as deep neural networks, support vector machines, and back-propagation algorithm) face some challenging issues such as: intensive human intervention, slow learning speed, over-fitting problems, and poor learning/computational scalability [1]. To overcome these challenges, extreme learning machine (ELM) was introduced in 2006 by Huang, Zhu, and Siew at Singapore [2]. See Figure 1 for more details [3].

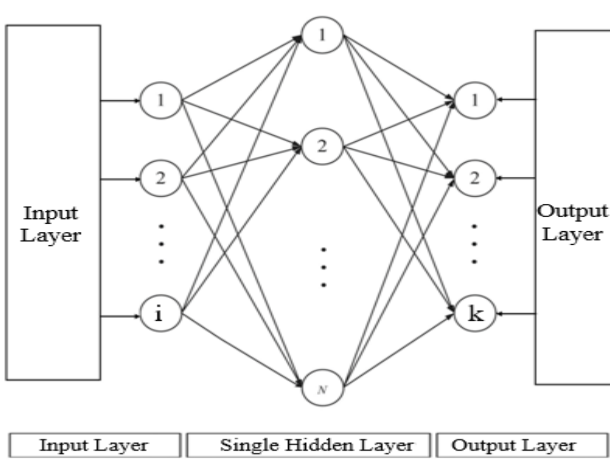

Figure 1 Architecture of ELM model [3]

Since then ELM has been a popular topic in the fields of machine learning and artificial neural networks.

An extreme learning machine (ELM) is basically a modified version of an artificial neural network. We get an extreme learning machine when you subtract propagation from a classic feed-forward neural network with one hidden layer. ELM is a single-hidden layer feedforward neural network, in which the parameters connecting the input layer and the hidden layer are generated randomly. It is basically the idea of a random projection followed by linear regression. The traditional neural network is complex and time-consuming. This has been a major bottleneck for many practical applications. ELM has the advantages of a simple, fast learning/training process, good generalization performance for multiple tasks, and good robustness.

As a feed-forward neural network, the ELM can be implemented in two steps. The first step is to randomly generate the weights connecting the input and the hidden layers. The second step is to calculate the output weights by the least-square method [4]. The learning speed of ELM
can be thousands of times faster than the traditional back-propagation (BP) learning algorithm. ELMs can be either single-layer or deep-learning-based and are quite common in China today.

Various variants or extensions of the original ELM have been proposed in the literature to improve its stability, sparsity, and accuracy under specific conditions or applications. Such variants include incremental ELM, evolutionary ELM, online sequential ELM, voting-based ELM, ordinal ELM, pruned ELM, memetic ELM, manifold regularized ELM, self-adaptive ELM, weighted or unweighted ELM, two-dimensional ELM, orthogonal ELM, and symmetric ELM [5].

II. Applications

Extreme learning machines (ELMs) are primarily applied to supervised learning problems. Only a few existing studies on ELMs have dealt with unsupervised learning. ELMs have proven to be efficient and effective learning mechanisms for pattern classification and regression, clustering, sparse approximation, compression, pattern recognition feature learning, forecasting, and diagnostics. See Figure 2 [6].

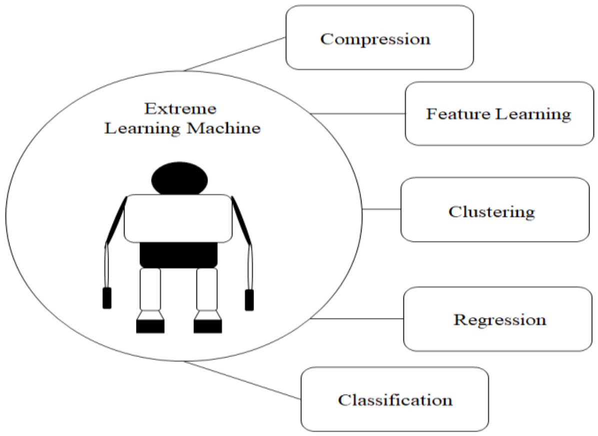

Figure 2 Basic roles of ELM [6]

Classification may be regarded as the analogue of regression when the variable being predicted is discrete instead of being continuous. ELM is an effective classifier. For example, intrusion detection systems (IDS), which is known as a promising technique to counter external intrusions or internal attacks on computer security attributes (i.e., confidentiality, integrity and availability) use some classifier as the core module of anomaly detection [7]. Classification is also an important issue in remote sending. Image classification is a difficult pattern recognition task in machine learning. The three classification problems relating to human behavior analysis are the recognition of a human face, facial expression, and activity.

Online sequence-ELM has been used to solve time-series prediction problem, such as stock forecast, weather forecast, and passenger count forecast. ELM has been used in several wireless communication applications such as UWB and 60 GHz systems. It is also suitable for online learning.

Other applications include RF power amplifier (which are key building blocks of wireless radio systems), medical diagnosis, human robot, electric power systems, credit scoring, economics, signal processing, and automatic control [8].

III. Challenges

Compared with conventional learning algorithms, ELM provides extremely faster learning speed, uses better generalization performance, and can be easily used with least human intervention. In spite of these inherent advantages, ELM faces some challenging issues include the following [9]:

(1) It does not adequately address the problem of structure complexity.
(2) It does not account for uncertainties in the data stream.
(3) It cannot handle the concept of drifting in the data streams.
(4) It suffers from the high dimensionality due to the absence of the feature selection scenario in the training process.
(5) Its accuracy is drastically sensitive to the number of hidden neurons so that a large model is usually generated.

The black-box character of extreme learning machines is a major issue that repels engineers from applying them in unsafe automation tasks. One problem here is choosing the number of hidden neurons. There is the lack of a general framework for ELM to integrate multiple heterogeneous data sources for classification.

In practical applications, ELM has slow response speed and low generalization ability for unknown test data. Its performance has been shown to deteriorate substantially and becomes unstable in the face of large and complex data problems.

IV. Conclusion

ELM is a new algorithm for single-hidden layer feed-forward artificial neural network. Its two basic characteristics are universal approximation capability with random hidden layer and various learning techniques that can be easily implemented [10]. It has been widely used in various fields to overcome the problem of low training speed of the traditional neural network. It is becoming popular in the machine learning community and has attracted considerable research efforts because of its simple form, easy-to-use advantage, and high computational efficiency. However, several problems with ELM still remain open for investigation [11,12].

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