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A self adaptive harmony search based functional link higher order ANN for non-linear data classification

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ABSTRACT

In the data classification process involving higher order ANNs, it's a herculean task to determine the optimal ANN classification model due to non-linear nature of real world datasets. To add to the woe, it is tedious to adjust the set of weights of ANNs by using appropriate learning algorithm to obtain better classification accuracy. In this paper, an improved variant of harmony search (HS), called self-adaptive harmony search (SAHS) along with gradient descent learning is used with functional link artificial neural network (FLANN) for the task of classification in data mining. Using its past experiences, SAHS adjusts the harmonies according to the maximum and minimum values in the current harmony memory. The powerful combination of this unique strategy of SAHS and searching capabilities of gradient descent search is used to obtain optimal set of weights for FLANN. The proposed method (SAHS–FLANN) is implemented in MATLAB and the results are contrasted with other alternatives (FLANN, GA based FLANN, PSO based FLANN, HS based FLANN, improved HS based FLANN and TLBO based FLANN). To illustrate its effectiveness, SAHS–FLANN is tested on various benchmark datasets from UCI machine learning repository by using 5-fold cross validation technique. Under the null-hypothesis, the proposed method is analyzed by using various statistical tests for statistical correctness of results. The performance of the SAHS–FLANN is found to be better and statistically significant in comparison with other alternatives. The SAHS–FLANN differs from HS–FLANN (HS based FLANN) by the elimination of constant parameters (bandwidth and pitch adjustment rate). Furthermore, it leads to the simplification of steps for the improvisation of weight-sets in IHS–FLANN (improved HS based FLANN) by incorporating adjustments of new weight-sets according to the weight-sets with maximum and minimum fitness.

1. Introduction

1990s saw a boom in the growth of data collection in almost every field – web, business management, e-commerce, remote sensors, microarrays gene expression, scientific simulations, production control and engineering design, transactions, stocks, bioinformatics, etc. And, since then there was a rise in the need of automated extraction of valid, unknown, novel and potentially useful information from the data in large databases which gave birth to many data analysis methodologies including data mining, business intelligence, etc. Data analysis is an analytical process of examining data to discover useful information and draw conclusions, which in turn, help in the decision making process. It integrates diversified techniques under statistics, engineering and science. Data mining is a data analysis process of identifying novel, understandable and previously unknown patterns in data, which acts as decision support system. Most tricky and challenging decision making processes in day to day human life is classification that helps to make decision from past experience. In data mining, classification is defined as a variety of data analysis process that can be used to assign important classes to unknown patterns. Classification task predicts definite class labels and constructs a model based on the training data set, which is used to classify anonymous patterns.

Many classification tasks have been proposed in recent years from emerging areas of science and engineering which comprise of document classification [1–3], sentiment classification [4–7], fault classification [8–11], text classification [12–14], image classification [15–18], gene expression classification and bio medical data classification [19–23] and others [24–30], which has given new shape, motivation and direction to the application of classification task in data mining. Although a good number of traditional classification methods are proposed by many researchers [31–35], for the first time, Zhang et al. [35] realized that artificial neural network models

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are alternative to various conventional classification methods which are based on statistics. The artificial neural networks (ANNs) are capable of generating complex mapping between the input and output space and thus they can form arbitrarily complex nonlinear decision boundaries. Along the way, there are already several artificial neural networks, each utilizing a different form of learning or hybridization. As compared to higher order neural network, classical neural networks (for example, MLP) suffer from slow convergence and are unable to automatically decide the optimal model of prediction for classification. In the last few years, to overcome the limitations of conventional ANNs, some researchers have focused on higher order neural network (HONN) models [36,37] for better performance. MLP is the most frequently used ANN model to solve real world complex classification problems. However, in MLP, the no. of hidden layers and number of neurons in the hidden layer change depends on the nature and complexity of the problem. The training of MLP is more complex due to the fact that the number of weight adjustments increase with the increase in number of layers and number of neurons in each layer. To address this intricacy associated with MLP, Pao [38] and Pao et al. [39] have suggested to use a single layer neural network (without hidden layer) which can be considered as an unconventional approach. The functional link higher order ANN (FLANN) proposed by them may be suitably used because of faster convergence rate, smaller computational load and less complex architecture as compared to MLP. FLANN is basically a flat network without hidden layers which makes it simple for learning and weight adjustment. Notwithstanding the fact that it has a single-layer network, it is capable to handle non-linear separable classification task as compared to MLP.

Functional link artificial neural network (FLANN) [38] utilizes the higher combination of its inputs [39,40] and has been successfully applied in a wide spectrum of applications such as pattern recognition [41,42], classification [43–45], channel equalization [46] , system identification [47–52], etc. Almost all the higher order ANNs (HONNs) including functional link higher order ANN (FLANN) are sensitive to random initialization of weight and rely on the learning algorithm adopted. Although a selection of efficient learning algorithm for HONNs help to improve the performance, but initialization of weights with optimized weights rather than random weights also plays an important role in the efficiency of HONNs. Various benchmark meta-heuristic optimization algorithms like genetic algorithm [53,54] and particle swarm optimization [55] are successfully used to address the issue of random initialization of weight in FLANN. These optimization algorithms are used to select best set of weights for FLANN models for various non-linear data analysis. Few negative aspects of these implementations are the requirement of various complicated mathematical operators like: (i) mutation and crossover operator in GA (ii) Position and velocity calculation and updation in PSO etc. The performance of these models are highly dependent upon the way of implementation of these mathematical operations (like selection of crossover operation, mutation operation and mutation rate) and any change in these factors may lead to increase in time and space complexity of the algorithm. Keeping these facts in mind, in this study, the meta-heuristic optimization algorithm: harmony search [56] and its variants (improved HS [57] and self-adaptive HS [58]) are used with FLANN model with gradient descent learning scheme for classification. The HS algorithms have few mathematical requirements as compared to earlier meta-heuristic optimization algorithms and those can be easily used for optimization of weights of FLANN model.

2. Literature survey

In this paper, an attempt has been made to design FLANN model with competitive learning based on a popular meta-heuristic optimization algorithm for classification of benchmark datasets considered from well known machine learning data repository. Prior to this, Patra et al. [59] have proposed FLANN model for prediction of financial indices and have used other Chebyshev neural network model with Chebyshev polynomial functional expansion. From the simulation studies they found that, the performance of FLANN and chFLANN are nearly equivalent. Also, the training time for FLANN and chFLANN is almost half of the MLP. It is found that FLANN and chFLANN have less complex architecture and chFLANN is better among the three ANNs (MLP, FLANN and chFLANN) in terms of better prediction capability. A FLANN based classification method with a least complex architecture as compared to MLP is anticipated by Misra and Dehuri [60] and the proposed method is found to be efficient in terms of ability of handling linearly non-separable classes by increasing the dimension of input space. In most of the cases, the performance and processing time of FLANN model is found to be better than other models. To address non-linear nature of classification problems, Dehuri et al. [61] have designed a hybrid functional link artificial neural network (HFLANN) based on genetic algorithm (GA) for optimal input feature selection by using functionally expanded selected features. They proved that, as compared to RBFN and FLANN with back propagation learning, HFLANN is found better for optimal set feature selection. A survey on FLANN is made and a PSO based back propagation learning is proposed by Dehuri and Cho [62]. They have emphasized on the basic concept of FLANN with associated basis functions, learning schemes, development of FLANNs over time and discussed a Chebyshev-FLANN with hybrid PSO-back propagation learning for classification. Patra et al. [63] suggested an efficient FLANN model for making stock price prediction of the closing price of US stocks and the proposed model is compared with MLP-based prediction model through several experiments. This proposed trigonometric FLANN has shown better performance over MLP by making more accurate predictions of stock prices. Prediction of the causing genes in gene diseases by FLANN model is proposed by Sun et al. [64] and compared with MLP and support vector machine (SVM). In this study, three classifiers (MLP, SVM, FLANN) have been implemented and the performance of FLANN classifier is found to be better than MLP and SVM. Chakravarty and Das [65] have proposed functional link neural fuzzy (FLNF) model to predict the stock market indices and compared with FLANN model in terms of root mean square error. The simulation results have been demonstrated to claim the better performance of FLNF over FLANN and they used PSO to address the the local minima issue in back propagation learning. Classification of online Indian customer behavior by using FLANN is proposed by Majhi et al. [66] which is better than the other statistical approaches. The proposed FLANN model shows superior classification performance as compared to discriminant analysis and also the authors suggested that, it can be improved further by providing psychographic and cultural information. A compact and accurate hybrid FLANN classifier (HFLNN) has been proposed by Dehuri and Cho [67] by selecting an optimal subset of favorable input features. By eliminating features with fewer or no predictive information, this method is found better as compared to FLANN and RBFN. Bebarta et al. [68] have used FLANN and its variants (Power FLANN, Laguerre FLANN, Legendre FLANN and Chebyshev FLANN) for stock price index forecasting and they have compared the results by using various performance measures (standard deviation error, squared error etc.). Mishra et al. [69] have used FLANN classification model based on bat inspired optimization and compared with FLANN and hybrid PSO based FLANN model. In this paper, bat algorithm has been used to update the weight of the FLANN, which results high classification accuracy. Simulation results show that bat algorithm based FLANN outperform FLANN and hybrid PSO based FLANN classifiers. The Chebyshev FLANN classifier with various dimension reduction strategies is suggested by Mahapatra et al. [70] for cancer classification. In this proposed method, initially PCA, FA, DFT and DCT techniques have been used to reduce the dimension of the data and then Chebyshev FLANN classifier is applied for better classification.