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A genetically optimized neural network model for multi-class classification

Arpit Bhardwaj*, Aruna Tiwari, Harshit Bhardwaj, Aditi Bhardwaj

Computer Science and Engineering Department, BML Munjal University Gurgaon, India, Computer Science and Engineering Department, Indian Institute of Technology Indore, Indore, India

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ABSTRACT

Multi-class classification is one of the major challenges in real world application. Classification algorithms are generally binary in nature and must be extended for multi-class problems. Therefore, in this paper, we proposed an enhanced Genetically Optimized Neural Network (GONN) algorithm, for solving multi-class classification problems. We used a multi-tree GONN representation which integrates multiple GONN trees; each individual is a single GONN classifier. Thus enhanced classifier is an integrated version of individual GONN classifiers for all classes. The integrated version of classifiers is evolved genetically to optimize its architecture for multi-class classification. To demonstrate our results, we had taken seven datasets from UCI Machine Learning repository and compared the classification accuracy and training time of enhanced GONN with classical Koza's model and classical Back propagation model. Our algorithm gives better classification accuracy of almost 5% and 8% than Koza's model and Back propagation model respectively even for complex and real multi-class data in lesser amount of time. This enhanced GONN algorithm produces better results than popular classification algorithms like Genetic Algorithm, Support Vector Machine and Neural Network which makes it a good alternative to the well-known machine learning methods for solving multi-class classification problems. Even for datasets containing noise and complex features, the results produced by enhanced GONN is much better than other machine learning algorithms. The proposed enhanced GONN can be applied to expert and intelligent systems for effectively classifying large, complex and noisy real time multi-class data.

1. Introduction

Multi-class classification involves training of instances for different categories so as to further enable the identification of categories for various unknown instances. Data classification is one of the biggest problems due to the amount of growing data nowadays. It finds its application in many real world problems, like fraud detection, medical diagnosis, face recognition, speech recognition, vehicle detection in military warfare and knowledge extraction from databases (De Chazal, Dwyer, & Reilly, 2004; Ng & Gong, 2002; Zhang, Gao, & Lou, 2007; Iounousse, Er-Raki, El Motassadeq, & Chehouani, 2015; Bhardwaj & Tiwari, 2013).The field of data classification is receiving increased importance due to unpredictability and complexity of real world data. A classification algorithm require huge amount of accuracy and reliability which is very difficult for human programmers. Therefore, there is an immense need to develop an automated computer based classification systems (De Chazal, Dwyer, & Reilly, 2004) which can classify the required objects.

Artificial Neural Networks (ANN)(Hopfield, 1988), is a very popular machine learning technique which is biologically inspired by the anatomy of human brain. It offers a great potential for multi-class classification. Recently, there have been number of reports on applying ANN techniques to range of classification problems (Aprile, Castellano, & Eramo, 2014; Grbatinić, Marić, & Milošević, 2015; Iounousse, Er-Raki, El Motassadeq, & Chehouani, 2015; Lam et al., 2014; Mohammed, Badr, & Abdelhalim, 2015; Nie, Jin, Fei, & Ma, 2015). It consists of good adaptation/learning ability. Multilayer Perceptron (MLP) (Haykin, Haykin, Haykin, & Haykin, 2009) is one of the important artificial neural networks and back-propagation algorithm is one of the most widely used MLP training technique, which iteratively changes the weights between the neurons in a direction that minimizes the error. Thus, ANN can easily adapt to new trends in data but the problem with this is its slow rate of convergence and the risk of being trapped in a local optimum (Rumelhart, Hinton, & Williams, 1985). Another problem with BPA is in deciding its structure; the number of layers, number of

* Corresponding author.
E-mail addresses: arpit.bhardwaj@bml.edu.in, phd12110102@iiti.ac.in (A. Bhardwaj), artiwari@iiti.ac.in (A. Tiwari), harshitbhardwaj15@gmail.com (H. Bhardwaj), aditi.bhardwaj@bml.edu.in (A. Bhardwaj).

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hidden neurons in each layer and the connectivity between them. Koza (1992) brought a new dimension in this area, by using genetic evolution to optimize both, the weight and structure of a neural network. There have been many other works in this area(Khan, Ahmad, Khan, & Miller, 2013; Palmes, Hayasaka, & Usui, 2005; Rivero, Dorado, Rabuñal, & Pazos, 2010; Tsai & Lin, 2011; Turner, Dudek, & Ritchie, 2010). That motivates a new research dimension to model a hybrid solution i.e. evolution of artificial neural network using genetic programming. Recently Bhardwaj and Tiwari (2015) proposed a novel Genetically Optimized Neural Network (GONN) model which finds the optimal structure and weights of neural network architecture using Genetic Programming (GP) for WBCD database which is a two class problem. The results showed that GONN outperformed the other work from literature for WBCD database.

The aim of this paper is to develop an expert and intelligent system that can able to classify multi-class data. The reason for developing such system is that many algorithms work better for binary classification but they are not able to produce better results when they are applied on multi-class data. Therefore, in this paper, an enhanced Genetically Optimized Neural Network (GONN) model for multi-class classification is proposed which is an extension of Genetically Optimized Neural Network (GONN) model for two class problem (Bhardwaj & Tiwari, 2015). In this enhanced GONN model, we used a multi-tree representation, which integrates multiple GONN trees, each individual is a single GONN classifier and enhanced classifier is an integrated version of individual GONN classifiers for all classes. This amalgamated classifier is evolved in search of best classifier using modified crossover and mutation operators (Bhardwaj & Tiwari, 2015) that has the ability to classify any of the class in one single evolution. To measure the performance of the proposed algorithm we used seven datasets from the UCI Machine Learning Repository (Frank & Asuncion, 2010). It is observed that the proposed algorithm yielded a very high accuracy with lesser amount of time for all the multi-class datasets with different training-testing partitions. Mann-Whitney two tailed test are used to show the significance of the results produced by our methods in comparison to other methods. To show the dominance of our approach, we compared our method with a classical Koza and Rice (1991) model, classical Back propagation neural network (BPNN) (Hagan, Demuth, Beale, & De Jesús, 1996) and also with recently proposed algorithms applied on the multi-class data. The results show that our approach works well with the multi-class data and outperforms the other well-known machine learning methods like Neural Network (NN) (Örkcü & Bal, 2011), Genetic Algorithm (GA) (Örkcü & Bal, 2011), Hybrid Decision tree classifier (Farid, Zhang, Rahman, Hossain, & Strachan, 2014), Hybrid Naive Bayes classifier (Farid et al., 2014) and Support Vector machine (SVM) (Ramanan, Suppharangsan, & Niranjan, 2007).

2. Related work

Many classification algorithms are binary in nature and must be extended for multi-class classification. These include neural networks, decision trees, k-nearest neighbor, naive Bayes classifiers, and support vector machines (Aly, 2005). Therefore, GONN can also be extended for Multi-class classification. There are many methods available in literature to utilize GP for multi-class classification problems. Binary Decomposition method also known as one-versus-all is the most widely used method in GP for multi-class classification. In this method, one classifier is evolved for each class, discriminating a particular class from other classes present in the data. The final decision is made by presenting the input vector to classifiers of all classes. The classifier with positive or highest output is declared the winner. Many researchers have explored this method for multi-class classification (Bojarczuk, Lopes, & Freitas, 2000; Kishore, Patnaik, Mani, & Agrawal, 2000; Loveard & Ciesielski, 2001; Smart & Zhang, 2005; Teredesai & Govindaraju, 2004). There are several other methods like all versus all (Hastie & Tibshirani, 1998), generalized error correcting output codes (Allwein, Schapire, & Singer, 2001) and error correcting output codes (Dietterich & Bakiri, 1995) have also been used to tackle multi-class classification problems by binary classification algorithms. Muni, Pal, and Das (2004) used a multi-tree representation for multi-class classification, where a single classifier is an integrated version of individual classifiers for all classes.

Various work has been proposed in the literature for solving multi-class classification (Fu & Lee, 2012; Lorena, De Carvalho, & Gama, 2008; Sánchez-Morillo, López-Gordo, & León, 2014) using different machine learning algorithms. Bhardwaj and Tiwari (2013) proposed a constructive crossover operator using Best First Search (BFS) technique. In this, they generated all the possible combination off-spring from the parent during crossover and find the 2 off-spring having the highest fitness among them and transfer them to the next generation. The problem with their approach is that it is very time consuming. If the size of the parent is large than many possible combination of off-spring can be generated. So, there is no point in adding BFS in crossover operation, because it increases the time required to reach the solution drastically. Jabeen and Baig (2013) proposed two stage learning for multi-class classification problems. In the first stage, the classifiers are trained for each class versus the remaining classes. In the second stage, the classifiers are integrated and treated as a single chromosome that can classify any of the classes from the dataset. They compared their method with binary decomposition method and other machine learning algorithms. MontañéS, Barranquero, DíEz, and Del Coz (2013) used Directed Binary Trees for multi-class classification and improved the classification performance and evaluation time of previous decomposition approaches based on trees. They showed that there results are very competitive with respect to the one-vs.-one approach. Kim and Choi (2015) proposed a hierarchical multi-class classification method using logical analysis of data (LAD) based on a one versus all (OvA)-binary tree, called hierarchical multi-class LAD (HMC-LAD). They construct an OvA-binary tree by partitioning a node with K($\geq$ 2) classes into two subnodes by identifying one distinct class from the remaining (K-1) classes repeatedly. They showed that the classification performance of HMC-LAD is superior to existing multi-class LAD algorithms and other supervised learning approaches. Ramanan et al. (2007) proposed SVM-based hierarchical multi-class classifiers such as Directed Acyclic Graph (DAG)-SVM and Unbalanced Decision Tree (UDT)-based SVM. They used SVM for binary tree partition at each node and UDT-SVM uses OvA-type binary tree

It is also been observed in past that hybrid algorithms performed better for classification with their counter parts (Aci, İnan, & Avci, 2010; Bhardwaj & Tiwari, 2015). In the last decade, lots of work has been done for solving multi-class classification problem using hybrid algorithms (Chou, Cheng, & Wu, 2013; Lee & Lee, 2015; Polat & Güneş, 2009). Farid et al. (2014) proposed two hybrid algorithms respectively for a DT classifier and a NB classifier for multi-class classification tasks. The first proposed hybrid DT algorithm finds the troublesome instances in the training data using a NB classifier and removes these instances from the training set before constructing the learning tree for decision making. Their second proposed hybrid NB algorithm finds the most crucial subset of attributes using a DT induction. Khashei, Hamadani, and Bijari (2012) proposed a new hybrid model of artificial neural networks for classification problems using the multiple linear regression models. The main aim of the proposed model is to use the unique advantages of the multiple linear regression models in linear modeling in order to overcome the linear modeling