Identifying Dyslexic Students by Using Artificial Neural Networks

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***Abstract*— There are millions of children suffering from dyslexia across the globe. Due to its implicit characteristics, the identification or the diagnosis of students with this learning disability has long been a difficult issue. In fact there is a little consensus about what is the best procedure to identify a child suffering from dyslexia. In some developed countries there are set procedures and adequate awareness for identification of this disorder. This paper proposes a systematic approach for identification of dyslexia and to classify or analyze potential cases more accurately and easily by use of ANN. The preliminary results obtained using test data were satisfactory and can be used as an effective tool to identify dyslexic child and obtaining adequate information before rushing to a specialist. Many efforts are required to make the model more accurate.**

***Index Terms*— Identification, Neural Networks, Dyslexia, Multi Layer Perceptron model, Supervised learning**

I. Introduction

The term "Learning disability" was coined in the year 1963. The national center for learning Disabilities has given LD the following definition – "A learning disability is a neurological disorder that affects the brain's ability to receive, process, store and respond to information. Learning Disability describes the unexplained difficulty a person of at least average intelligence has in acquiring basic academic skills. These skills are essential for success in school and work, and for coping life in general."

Dyslexia is a LD that manifests primarily as a difficulty with written language, particularly with reading and spelling. Evidence suggests that dyslexia results from differences in how the brain processes written and/or verbal language. Although dyslexia is the result of a neurological difference, it is not an intellectual disability. It occurs at all levels of intelligence, sub average, average, above average and highly gifted.

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The 2004 National Health Interview Survey [16] shows that almost 8% of children between 3-16 years of age had a LD in the United States. However, due to implicit characteristics of dyslexia, the identification of students suffering from this problem has long been a difficult issue. There is still a little consensus about what is the best procedure to distinguish dyslexic with a non dyslexic.[16]

In this research project, we have tried to adopt artificial neural networks to solve the dyslexia identification problems at an early stage. The remaining paper is organized as follows. Section 2 describes the basics of ANN; we then provide a brief overview of conventional diagnostic techniques used in section 3. The next section i.e. section 4 presents the ANN technique used for handling this problem, followed by actual implementation methodology in Section5. Finally section 6 contains the test results and the conclusion of the paper is drawn in section 7.

II. Review of ANN

A neural networks ability to perform computation is based on hope that we can replicate some of the flexibility and power of human brain by artificial means. Basically a neural network is machine that is designed to model the way in which the brain performs a particular task or function of interest. The network is usually implemented by using electronic components or is simulated in software on a digital computer.[11]

The property of neural network that is of primary significance is the ability of network to learn from its environment and the ability to improve its performance through learning. A neural network learns about its environment through an interactive process of adjustments applied to its synaptic weights and bias level. After completing the learning process successfully the network is ready to be deployed for independent functioning.[7]

Neural networks have been applied to an increasing number of real world problems of considerable complexity. The most important advantage is that artificial neural networks are capable of solving problems that are too complex for conventional technologies – problems that do not have an algorithmic solution or that solution is too complex to be found.

Though many application bibliographies exist in the field of biomedical research, however, none of these include an application in identification of dyslexic students. This project seems to be one of the first to attempt the use of ANN for addressing this challenging problem that has drawn the attention of many medical researchers.

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This study differentiates from the others as follows. First there is probably no reported study on using neural networks to identify the potential dyslexic students. So our project is perhaps a first attempt of its kind in this problem domain. Another distinguishing feature comes from its longitudinal nature. This project is based on test data, designed to cover the evaluation results of potential dyslexic students, between the years 2003 – 2007. The results obtained suggested that out ANN model would perform better than the ones reported in the literature, when implemented on actual data as well.

III. Conventional diagnostic techniques

Dyslexia is most commonly characterized by difficulties with learning how to decode at the word level, to spell and to read accurately and fluently. Dyslexic individuals often have difficulty "breaking the code" of sound - letter association i.e. the alphabetic principal, and they may also reverse or transpose letters when writing or confuse letters such as b, d, p, q specially in childhood.

Many individuals with dyslexic symptoms involving reading, writing and spelling also exhibit symptoms in other domains such as poor short – term memory, poor personal organizational skills and problems processing spoken language. Dyslexia is a lifelong condition for which there is no cure, but appropriate remedial instructions and compensatory strategies can help dyslexic individuals mitigate or overcome their difficulties with written language.

The conventional methods used for treating dyslexia are based on empirical findings from research. According to conventional techniques, a sever discrepancy between intellectual ability and academic achievement has to exist in one or more of these academic areas: Oral expression, Listening comprehension, Writing expression, Basic Reading skills, Reading comprehension and Mathematical calculations. These aforementioned parameters are commonly examined to evaluate whether a child is dyslexic or not.

The identification procedure normally followed can be segregated into four steps:

Step 1: Application for screening of potential dyslexic students by parents, teachers etc.

Step 2: Identification of potential dyslexic students by junior level LD specialist.

Step 3: Diagnosis of possible dyslexic students by senior level LD specialist.

Step 4: Final confirmation by special education specialists. Confirmed possible dyslexic students are then evaluated for a full year before admitting to special intensive counseling.

The above model suffers from some drawbacks. The first issue with the above procedure is the extensive time and resources are required. The time consuming nature of this procedure makes it very unappealing. Also in the current scenario there is no psychologist or counselor at the school level, to assist the identification related activities. The second issue with dyslexia identification is the lack of nationally regulated standard. As a result, the procedure and its results vary from place to place. Thus there is a lack of co ordination in diagnostic process.

In order to successfully identify and then treat the potential Dyslexic students, the above two issues must be resolved. In this project, we explore the potential of ANN techniques in solving this rather complex problem. [16]

IV. Early identification/diagnosis using ANN

Though commonly known as black box approach or heuristic method, in the last decade, artificial neural networks have been studied by statisticians in order to understand their prediction power from a statistical perspective. These studies indicate that there are a large number of theoretical commonalities between the traditional statistical methods, such as discriminant analysis, logistic regression, and multiple linear regressions, and their counterparts in neural networks, such as multi-layered perceptron, recurrent networks, and associative memory networks. [3]

In this project the use of NN in identifying potential dyslexic students is explored. Here we convert the identification problem into a classification one i.e. the aim is to categorize the potential dyslexic students in one of the two output categories viz. dyslexic and non – dyslexic. [2]

Multi layer perceptron (MLP) neural network architecture is known to be a strong function approximator for prediction & classification problems. MLP is capable of learning arbitrarily complex non-linear functions to an arbitrary accuracy level. Thus it is a candidate for exploring the rather difficult problem of mapping college performance to the underlying characteristics. The error back-propagation algorithm presents the best mapping; it is thus used in this approach.[14]

The inputs to the NN model are the evaluation test results of potential dyslexic students, which generally include testing of reading ability such as tests of rapid naming, short term memory evaluation and sequencing skills, non word reading to evaluate phonological coding skills, an IQ test to establish a profile of learning strengths and weaknesses. A brief description of the inputs chosen is given below.

4.1.1. Evaluation test result for symptoms of Speech/Hearing deficits: A questionnaire for this input field would look like:

(1) Difficulty learning the alphabet – Y or N
(2) Difficulty with word retrieval or naming problems – Y or N
(3) Difficulty with hearing and manipulating sounds – Y or N
(4) Difficulty distinguishing different sounds in words – Y or N etc

4.1.2. Evaluation test results in Reading and Spelling: The questionnaire for this section would be like the one given below:

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(1) Misspell words, leave vowels out of words – Y or N
(2) Difficulty in maintaining word order – Y or N
(3) Difficulty distinguishing among homophones such as "their" and "there" – Y or N
(4) Small written vocabulary even if having large spoken vocabulary – Y or N.

4.1.3. Evaluation test results for deficit in Writing and Motor skills: The possible questions for this test can be:

(1) Slower writing speed – Y or N
(2) Very poor handwriting characterized by irregularly formed letters – Y or N
(3) Use of inappropriate words when writing – Y or N

4.1.4. Evaluation test result for deficit in Mathematical abilities: The questions for assessing would be:

(1) Difficulty remembering mathematical facts – Y or N
(2) Difficulty in learning the sequence of steps when performing calculations – Y or N
(3) Slow response in mathematical drills – Y or N etc.

For the purpose of identification of potential dyslexic students all of these questionnaires must be answered. This is the main step of the implementation methodology, which is discussed in detail in the next section.

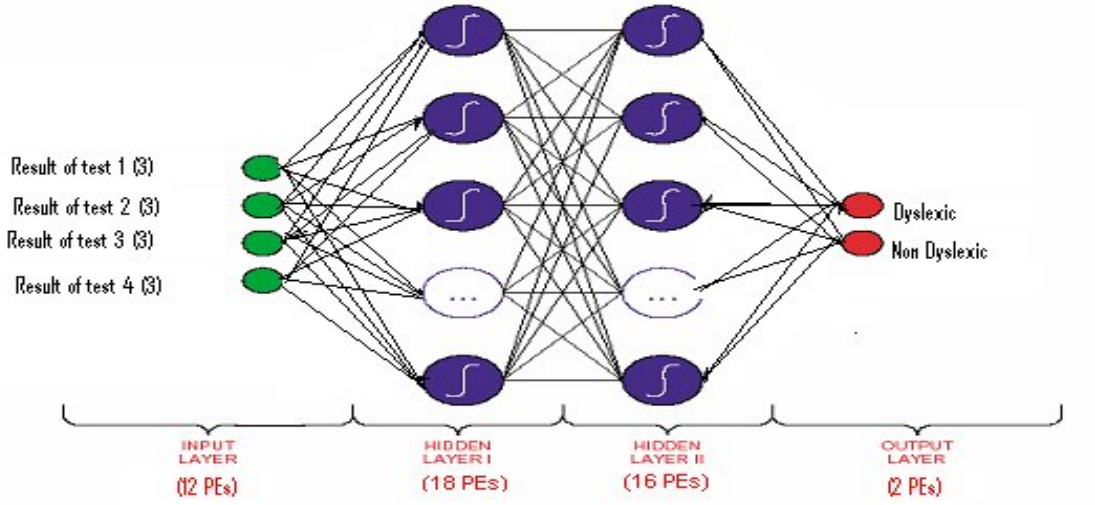

Figure 1: Multi layered perceptron model implementation for identification of dyslexic cases in children [15]

V. Proposed Implementation Methodology

First of all, take into account student's school assessment data for past five years. If the student has been continuously scoring very poor marks, then we presume that dyslexia identification tests are required. The next step is to fill up the questionnaires provided with our NN model. The questionnaires are automatically evaluated and result is shown as belonging to one of the three ranges:

(1) Less than 33%
(2) Between 33 and 45%.
(3) Greater than 45%

These three ranges for each of the tests form the categorical independent decision variables. These categorical independent variables are converted into 1 – of – N binary representations. Thus we get a number of pseudo representations that increases the independent variable count from 4 to 12. The neural network treats these pseudo representations as different mutually exclusive information

channels. All pseudo representations of a categorical independent variable are given a value of 0 except the one that holds true for the current case, which is assigned the value 1. For e.g. if we consider the evaluation test result for deficit in mathematics, if a child scores less than 33% marks then that input range would be set to 1 and the remaining two to 0. [10]

This is how the classification model is obtained. This model is trained by using the supervised training mode. The output is classified in one of the two output categories – Dyslexic or Non – Dyslexic.

Many researchers in the past few years have studied the performance of neural networks in predicting a variety of classification problems over a wide range of different business settings. Many of these studies, however, were based on a single experiment, and/or the method of selecting the training and testing samples was not clear. We believe that because of the stochastic nature of the neural network training, better experimental design methods are necessary to develop the objective performance measures of neural networks.

As opposed to using single neural network experiments to base our results upon, a more statistically sound experimental design methodology, called k-fold cross-validation is proposed. In k-fold cross-validation, also called rotation estimation, the complete dataset (D) is randomly split into k mutually exclusive subsets (the folds: D1, D2,.,, Dk) of approximately equal size. The classification model is trained and tested k times. Each time (t2 {1,2,., k}), it is trained on all

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but one folds (D\Dt) and tested on the remaining single fold (Dt). The cross-validation estimate of the overall accuracy is calculated as simply the average of the k individual accuracy measures.[6]. Since the cross-validation accuracy would depend on the random assignment of the individual cases into k distinct folds, a common practice is to stratify the folds themselves. In stratified k-fold cross-validation, the folds are created in a way that they contain approximately the same proportion of predictor labels as the original dataset. Empirical studies showed that stratified cross validation tend to generate comparison results with lower bias and lower variance when compared to regular k-fold cross-validation [6]. In this study, to estimate the performance of neural network classifier a stratified 10-fold cross-validation approach is used. In 10-fold cross-validation, the entire data set is divided into 10 mutually exclusive subsets (or folds) with approximately the same class distribution as the original data set (stratified). Each fold is used once to test the performance of the classifier that is generated from the combined data of the remaining nine folds, leading to 10 independent performance estimates. [6]

VI. Results

The aforementioned approach of using Neural Networks in this field aims to identify students suffering from dyslexia. This project was implemented on a test and trial basis, using test data on the evaluation version of the software NeuroSolutions5 and a maximum accuracy of 75% was obtained. This research project is perhaps one of the first attempts to use neural networks for addressing this challenging problem in diagnosis/identification of dyslexia. This model would be highly beneficial to:

(1) Parents of students – They will be able to diagnose their child's problem at an early stage and therefore go for appropriate treatment at the right time.
(2) Teachers/School Authorities – They would be benefited for they would come to know the exact percentage of its students suffering from dyslexia and thus provide them with suitable counseling. In this way their annual performance would also not degrade.
(3) Doctors/ Psychologists – They would draw benefits
(4) Young Students – They will draw maximum benefit. Their problem would be identified at an early stage so the net academic loss would be greatly reduced. They will get the due counseling at the right time and would also not feel inferior in comparison to other "bright" students

VII. Conclusion

Currently the identification of dyslexia affected students is a major issue, primarily due to the lack of proper identification methods. In this paper, we propose to apply ANN techniques to solve the dyslexia identification problem. The preliminary results obtained are fairly accurate and therefore suggest that this scheme is applicable to real data as well. However there is still much work to do in finding a combination of variables so as to develop a model of sufficient accuracy. With the availability of these novel methods of identification of dyslexia, it is expected that more and more cases of dyslexia would be discovered.

It is further expected that the ANN approach would lead to discovery of the various causes of dyslexia. This ANN model could also be adopted to forecast the type of dyslexia a student is suffering from. The results obtained might potentially benefit the education and medical community by providing new methods of diagnosis leading to elimination of unnecessary tests and thus saving time and resources.

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