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Research paper

Analyzing student performance using evolutionary artificial neural network algorithm

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Abstract

Educational Data Mining (EDM) and Learning Systematic (LS) research have appeared as motivating areas of research, which are clarifying beneficial understanding from educational databases for many purposes such as predicting student's success factor. The ability to predict a student's performance can be beneficial in modern educational systems. This research work aims at developing an evolutionary approach based on genetic algorithm and the artificial neural network. The traditional artificial neural network lacks predicting student performance due to the poor modeling structure and the capability of assigning proper weights to each node under the hidden layer. This problem is overwhelmed with the aid of genetic algorithm optimization approach which produces appropriate fitness function evaluation in each iteration of the learning process. The performances gradually increase the accuracy of the prediction and classification more precisely.

Keywords: *Educational Data Mining; Artificial Neural Network; Probabilistic Neural Networks; Evolutionary Artificial Neural Network.*

1. Introduction

The most powerful methodology to analyze useful information from the data warehouse is data mining. The task of data mining is predicting hidden information by the process of extraction to produce better decision-making. Data mining has extended its utilization on educational activities based on the performance of students, staff and managerial decisions. Data mining can also be termed as knowledge discovery from data (KKD) [1], [2]. Data mining is the multidisciplinary field which encompasses various areas like making learning, information technology, statistics, retrieval, artificial intelligence and visualization of data. The better mining application is widely balancing education system. The concept of educational data mining is rapidly growing in the field of education which focuses on any type of the educational institutions, while academic analyst is particularly related to institutional effectiveness and students performance issues. The scope of EDM includes the areas that directly impact the students of the institution.

EDM generally focused on broader range of data in the field of education institutions whereas analytics of academic's specifically concentrates on data related to effectiveness of institutions and retention of student problems. The areas which directly influence students are the main scope of the EDM. It also extends its knowledge discovery process including alumni relations, admission process and selection of course depending on the capability and interest of the students. [3]. Main objective of this research paper, makes to mine the information discover from the student database for civilizing the student act. Here by, data mining techniques such as supervised learning and unsupervised learning methods are used to evaluate the student performance. The investigation of performance can be done in numerous ways such as Overall Semester Mark, Age, Day Scholar/hostler, Board Studied, Attendance, Co-curricular Activities (Paper Presentation, Seminar attendance) and Standing Arrears. This research paper is organized as follows, section 2 discusses about the review of literature relevant to education data mining, section 3 clearly explains about methodologies used for this research work. Section 4 shows the Simulation Analysis and section 5 shows the experimental results carried throughout the process. Finally, section 6 concludes the research work with its findings.

2. Review of literature

Though there are several existing works done on the predicting students' academic performance. This section discusses about the some of the important existing works related to the problem of predicting the performance of the students.

Mustafa Agaoglu [4] in his research work concentrates on modeling the performance of students alone and developed an educational data mining process by building four different types of classification methods like decision tree, svm, ANN and discriminant analysis as the classifier. The performance was evaluated by collecting the dataset depending on the response of the students using accuracy, precision and recall metrics. The comparison of the classification proved that c5.0 produces best result in about Mentioned metrics. Additionally, the examination illustrates that the mentors' success depends on the students' perception. Tripti Mishra, Dr. Dharminder Kumar, Dr. Sangeeta Gupta [5] in their work based on the social, academic and several emotional skills the development of the prediction model is done. The simulation result shows that random tree classifier performs better than j4.8 classifier. Keno C. Piad, Menchita Dumlao, Melvin A. Ballera, Shaneth C. Ambat [6] in their work proposed a prediction model for employability of IT graduates with nine different important

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variables. For prediction many classification algorithms are used and the simulation output it is determined that logistic regression performs better with the accuracy rate of 78.4. Bipin Bih ari Jayasingh [7] proposed a method to analyze the learning characteristics of a particular batch from particular set of students. They collected sample dataset from a specific institution and on a specific environment. The dataset is related to inquiry and deductive learning bases and they are collected by distributing the questionnaire to two different batches of the students. The proposed system is designed, developed and it is tested twice after performing training the content with the aid of inductive way of technique and it is deployed using the relevancy of attributes, rules of discriminant belongs to discrimination class mining. The simulation results are compared using the bar charts and from the outcome it is observed that two different batches of leaners at different years definitely have different characteristic of learning. S. M. Merchán [8] devised a data mining approaches and methods for analyzing the performance of the students and developing a predictive model for determining the academic performance of the system Engineering Students. This method works in an iterative manner which discovers the results of the experience that is analyzed in each of the process iterations.

A new model on web based education system which is performed on the specific domain of programming languages chosen by each individual proposed by Konstantina Chrysafiadi and Maria Virvou [9]. The fuzzy knowledge state definer is applied to model a dynamic approach on determining and updating the knowledge level of students for all the domain knowledge concepts. The process is fully dependent on the fuzzy cognitive map which is used to denote the dependencies among the concern domain. This approach uses fuzzy sets to demonstrate knowledge level of students as a subcategory of the domain knowledge. M.Mayilvaganan, D. Kalpanadevi [10] in their research work focused on improvement of prediction and classification of expert skill based on the performance in academics. The work also shows the comparative analysis of c4.5 classifier, naïve Bayes classifier, KNN AODE and decision tree to determine the well suited algorithm for performing the analysis on students' performance using the weka tool.

The model on emerging interdisciplinary area of research which deals with the design and development of methods and explores the data on educational context was proposed by Cristobal Romero [11]. The computation approaches are used in the work to analyze the data in order to learn about the educational questions. The update research works are considered for their study of related works. First it details on the EDM and narrates about the variant group of user, types of environment related to education and the type of data they provide. The most common tasks in education environment is solved using data mining approaches and finally the future work of the proposed model is also clearly outlined. Pandey and Pal [12] on the base of the performance of the students they proposed a system with 600 students from various colleges of a specific university. With the attributes like language, qualification background and category it was determined that whether the new comer will be a performer or not using Bayesian Classification. Galit [13] in his work done a case study on student data to find out the learning behavior of them. The work also predict and to advise them about risk factors during final exams and make them to move in proper direction in both academics and of their carrier. Bray [14], in his study on private tutoring and its implications, observed that the percentage of students receiving private tutoring in India was relatively higher than in Malaysia, Singapore, Japan, China and Sri Lanka Pandey and Pal [15] piloted learning on the student performance using association rule mining to find the interestingness of the students opting for class teaching language. This will improvise the understanding of subjects taught by the staffs. C.Anuradha and T.Velmurugan[16] focused the data mining algorithms for the classification of the students based on the attributes selected reveals that the prediction rates are not uniform among the algorithms. The range of prediction varies from 61-75 %. Moreover, the classifiers perform differently for the five classes. The data attributes that are found to have significantly influenced the classification process are First and Second classes.

Cluster based analyses on the 400 students among them 200 are girls and remaining 200 are boys from a senior secondary school done by Khan [17]. The main objective of this work is to produce the prophetic assessment of diverse events of reasoning, disposition and demographic variables for accomplishment at higher secondary level in science group. The assortment was constructed on cluster sampling method in which the complete population of concentration was distributed into clusters, or groups, and a arbitrary model of these clusters was designated for additional analyses. The data mining tool that assist the user to examine data from various dimensions, categorizing and summarizing the associations which are determined using the mining techniques are explained by Han and Kamber [18]. Ayesha, Mustafa, Sattar and Khan [19] explain in their work about the clustering of students based on their learning activities using k-means algorithm. The outcome of the process greatly helps the instructors as well as the students for improvising them with the aid of applying the data mining techniques on students information related data. Bhardwaj and Pal [20] devised a technique for improvising the performance of the 300 students from various college of same course under a specific university. The Bayesian model is used for designing and developing the prediction model with 17 different attributes and selecting the most potential attributes which contributes more in determining the highly correlated attributes to find the student academic performance. Al-Radaideh, et al [21] conducted study on final year graduate students using decision tree. Three different classifiers are used for comparison using ID3, C4.5 and Naïve Bayes to determine the performance of the proposed system. The proposed tree model performs better than other three models.

3. The methodology

Student's performance can be evaluated based on proposed Evolutionary Artificial Neural Network algorithm and tested with different algorithms namely Artificial Neural Networks and Probabilistic Neural Networks (PNN). The research methodology followed and working principle of Genetic algorithm is clearly discussed.

a) Working principle of genetic algorithm

Genetic Algorithms were invented to mimic some of the processes observed in natural evolution. As such they represent an intelligent exploitation of a random search used to solve optimization problems. GA is encompassed of binary bit strings as populations. Initially the values are identified randomly and then based on it the fitness value of each parent is evaluated. In the given complex space the combination of ones and zero are the possibilities that may be searched in the given search space. The relations among them are identified during the evaluation process by fitness value among them and they are ranked accordingly. The Genetic algorithm is used in this education data mining to determine the performer among the student dataset. Here each student attributes values are converted to zeros and ones depending on their record set. The fitness value of each student is evaluated using the attributes that is taken into the consideration for determining the performance.

This process is not just included for using it while the above said to process are insufficient but by the previous operations due to its absenteeism from the generation, either by a arbitrary coincidental or because it has been rejected. It only implies the change of a 0 for a 1 and vice-versa.

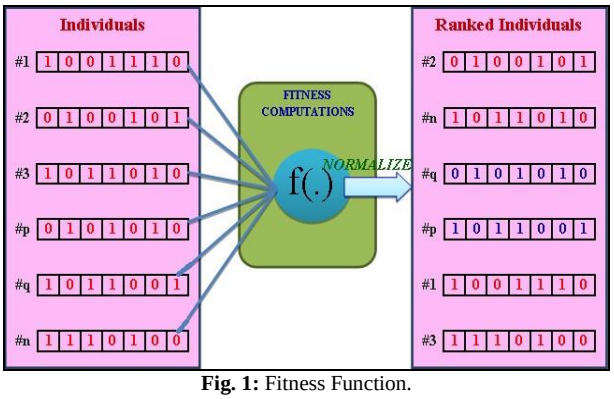


Fig. 1: Fitness Function.

The students with highest fitness value are selected for the next iterations and they are ranking depending on this value. Genetic algorithms have three main operations which are

i) Process of Selection.
ii) Process of Cross over among parents and
iii) Process of Mutation among parents.

i) Selection it is the process of selecting individual strings based on their fitness value. The strings with highest fitness value have more chance to survive in the next upcoming iteration.



Fig. 2: Example GA Population Solutions And Selection Operation.

ii) Crossover it is a process which works under two different steps. In the first step pairs of strings mated with their strings in a random manner and they become the parents of the two different two new bit strings which is known as offspring. During the second process it chose's a particular place in the bit string and interchange all the characters of the parents after the crossover point. This is the way of producing artificially the matting process in which the DNA of two parents will find the DNA for newly born offspring.



Fig. 3: Genetic Algorithm Crossover Operations.

In figure 3, the site of crossover is 8 so next to 8th bit the values of parent 1 and parent 2 get swapped and outcomes as child 1 and child 2.

iii) Mutation operator: Due to the consideration of probability factor which specifies that there is a chance for certain bit may be able to be changed due to the previous operations.

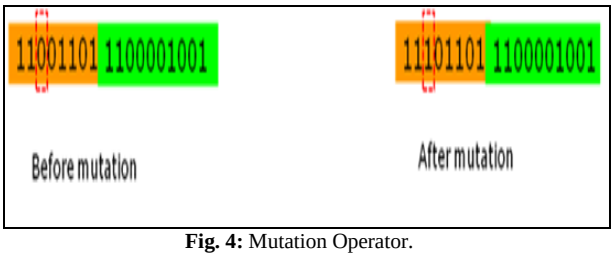


Fig. 4: Mutation Operator.

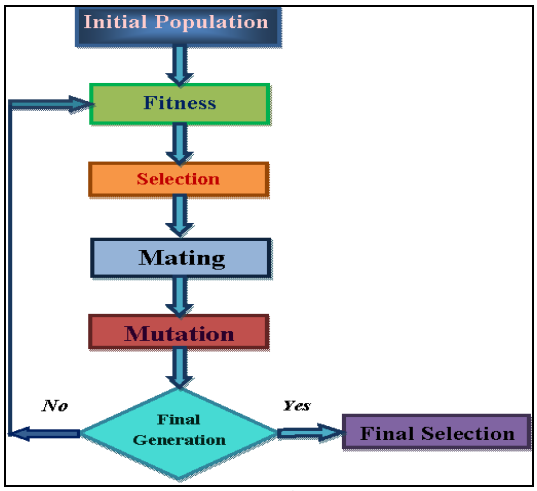


Fig. 5: Overall Process of Genetic Algorithm.

Procedure for Genetic Algorithm complete flow:
step1: Initialization of population
step2: Determining fitness of population from the selected search space
step3: While (termination criteria is met) do
Apply selection of parents
Using probability (pc) perform Crossover
Perform Mutation along with probability pm
Interpret and apply the fitness calculation
Select the highest fitness value holder as Survivor
Among the selected population determine best
step4: Return best

b) Architecture of artificial neural networks

In General the artificial neurons in ANN are structured in layers. A Basic structure of ANN contains three types of layers that are interconnected and named as input layer, hidden layer and output layer. Each layer composed of one or more nodes, denoted by the small circles as shown in the figure 6.

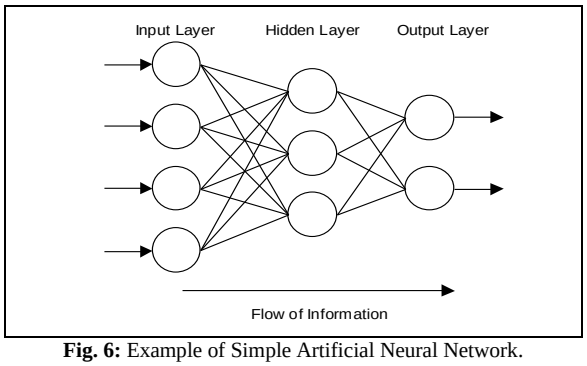


Fig. 6: Example of Simple Artificial Neural Network.

The link between the artificial neural nodes signifies the stream of information from node to the next node. In the figure the flow starts from the input node to the output but some other network types may also have feedback links. The input layer nodes are called as submissive because they don't change the data. They receive the single data from the external source and duplicate them to their many outputs. The layers of hidden and output are referred as active nodes i.e., they change the value of data received by

them. All the hidden nodes are fully interconnected with the input nodes.

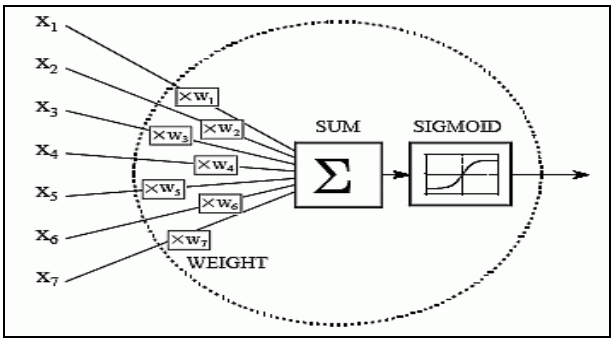


Fig. 7: Neural Network Active Node in Hidden Layer and Output Layer.

The value received by the hidden node is multiplied by a set of predetermined numbers termed as weights. These weights are summed together to produce a single value it is shown in the figure 7 by the symbolΣ. Then a nonlinear mathematical function is applied to the value which controls the output of the nodes. This nonlinear function is represented in the S shaped curve and the function is termed as sigmoid. The input of the sigmoid function is between -∞ and +∞, whilst its output can merely be between the interval of 0 and 1.

Like the hidden layer the same process is followed in the output layer's active node it also integrates and alters the data to generate the output. Generally neural networks can have whichever number of layers and nodes on each layer. For analysis of detecting the target the output layer contains only one single node. The value of the output node is threshold to produce a sign of negative for absence or positive sign for presence depending on the input data. Even though the function of processing unit looks very simple and there is no interesting inference in its process the complete prospective and its influence is mainly when these nodes are started interlinked or interconnected. The manner in which these artificial neurons are linked is termed as topology or architecture of an ANN [23]-[29].

c) Probabilistic neural networks (PNN)

PNN is a feed forward neural network formed by Ibrahim [22]-[29]. It is established based on Bayesian network and Kernel Fisher differentiate analysis. In a PNN, the actions are systematized into a multilayered feed forward network. First layer is input layer in which one neuron is existent for each autonomous variable. The next layer is the hidden layer. This layer comprises one neuron for each set of training data. It not only stores the values of the each predictor variables but also stores each neuron along with its target value. Next is the Pattern layer. In PNN networks one pattern neuron is present for each category of the output variable. Last layer is output layer. At this layer weighted votes for each target category is compared and selected. PNN are known for their ability to train quickly on sparse datasets as it separates data into a specified number of output categories. The network produces activations in the output layer corresponding to the probability density function estimate for that category. The highest output represents the most probable category. Design and Development of Proposed Evolutionary approach based Artificial Neural Network in Student Academic Performance Prediction.

This section gives a brief note on the use of a hybrid approach on artificial neural network (ANN) and genetic algorithm (GA) termed as Evolutionary Artificial Neural Network-GA approach for predicting Students Performance.

d) Evolutionary ANN approach (EVANN)

In this method, genetic algorithm is used assigning and updating the hidden nodes weight in the process of learning phase. A neural network with a pattern of 'l-m-n' is measured for valuation it means there are single input node, m number of hidden nodes and n number of output nodes. In this paper, linear based activation function is applied on the outcome of the input node where the output of the input layer is treated as the input of the hidden layers and it is denoted as

$$O_i = I_i \tag{1}$$

The sigmoidal function is applied for both hidden and the output layer. The representation of sigmoid function is denotes as squashed-S function. The output of hidden layer 'Out'$_h$ is considered as the input of hidden layer 'Inp'$_h$ and it is denoted as:

$$Out_h = \frac{1}{1+e^{-Inp_h}} \tag{2}$$

The output of the output layer 'Out'$_o$ for the input of the output layer 'Inp'$_o$ is represented as

$$Out_o = \frac{1}{1+e^{-Inp_o}} \tag{3}$$

The amount of weights N necessary for this network with the configuration of 'l-m-n' can be calculated using the subsequent calculation:

$$N = (l + n) * m \tag{4}$$

With every weight (gene) existence a real number and presumptuous the amount of digits (gene length) in weights to be d. The distance of the chromosome L is calculated using the subsequent calculation:

$$L = N * d = (l + n) * m * d \tag{5}$$

For defining the fitness value of every chromosome, weights are mined from every chromosome by the subsequent calculation:

$$W_k = \begin{cases} -\dfrac{x_{kd+2}*10^{d-2} + x_{kd+3}*10^{d-3} + \ldots + x_{(k+1)d}}{10^{d-2}} & if\ 0 <= x_{kd+1} < 5 \\ +\dfrac{x_{kd+2}*10^{d-2} + x_{kd+3}*10^{d-3} + \ldots + x_{(k+1)d}}{10^{d-2}} & if\ 5 <= x_{kd+1} <= 9 \end{cases} \tag{6}$$

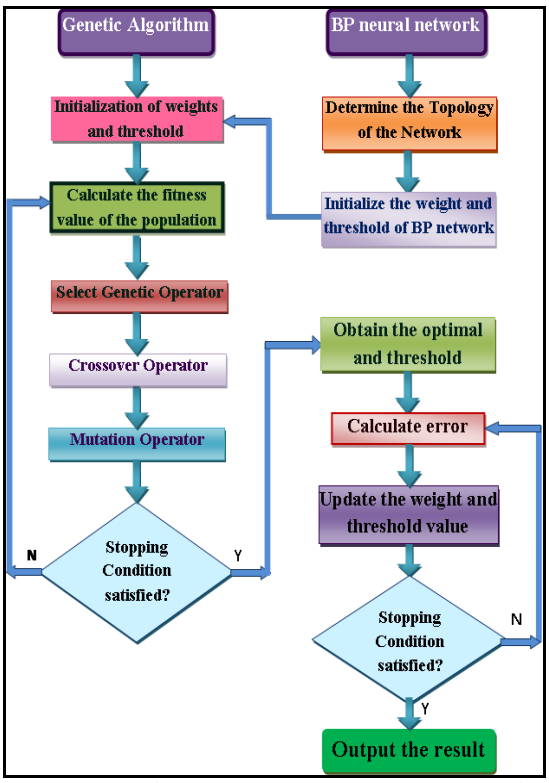


Fig. 8: Work Flow of Evolutionary ANN Based Student Performance Prediction.

The Data were collected through questionnaire from 1300 undergraduate students during the even semester of 2016 in various colleges. Student's records are collected and preprocessed to convert it into a meaningful data. The collected attribute details are as follows: Student name, data of birth, gender, locality, father and mother name, parents education details, the economic status of the family, the attendance for the semester, the result obtained in the previous semester are collected and from it only the relevant details essential for the analysis of the student performance is taken of consideration and they are listed in the below table.

Table 1: Student Database Consist of the Following Information or Features

Attributes	Description	Possible values
Gender	Gender (male, female)	M, f
Locality	Living locality	Urban, Rural
paredu	Parental education	Edu, unedu
Eco	Economic status	High, Low
Attendance	Class attendance	High, Low
Result	Students' result	First, Second, Third, Fail

The software tool used for design and development of this proposed system and to perform the simulation analysis on the Excellency of the proposed EVANN with ANN and PNN is done using MATLAB tool. The student's database is collected and stored in the matlab file format. With the help of libraries available in the tool the genetic algorithm and the artificial neural network integrated approaches were developed.

4. Simulation analysis

The performance result was tested with algorithms and follows neuron topology for generating rules for simulation. The followed network topology and measurements evaluated are clearly based on student academic performance prediction.

a) The network topology of neuron networks

In this study, the Back Propagation neuron network has three layers including one hidden-layer. The neural networks models are trained with 4 neurons as input data while 3 neurons for the hidden layer, and 1 neuron for output layer. The neuron transferring function in hidden-layer is sigmoid function in matlab represented as tansig, and that in output-layer is purely linear is represented as purelin. And the training function is traingdm. The training error precision is 0.0001.

b) Evaluation Measures used to analyze Student Academic Performance Prediction

There are several measures used to determine and observe the performance accuracy of the proposed prediction model. These measures highly depended on the value of predicted and actual outcomes. The model is designed using the matlab code. The Evaluation metric used in this work are described below:

Magnitude of Relative Error (MRE): It is computed finding the ration of difference between actual and predicted value with the actual value. The formula for this metric is:

$$\text{MRE} = \frac{|Actualvalue - predictedvalue|}{Actualvalue} \quad (7)$$

Mean Magnitude of Relative Error (MMRE): MMRE is measure of the mean of MRE. The formula is follows:

$$\text{MMRE} = \sum_{i=1}^{N} MRE_i \quad (8)$$

Pred: Pred is computed by the predicted values whose MRE is a smaller amount than or equal to a specified value. The formula for this measure prediction accuracy where D is the number of predicted values which are less than or equal to the specified value, r is the quantified value and H is the total number of cases.

$$\text{Pred (r)} = \frac{D}{H} \quad (9)$$

5. Results and discussion

The student performance analysing process using evolutionary Artificial Neural Network Algorithm is compared with two algorithms namely Artificial Neural Network (ANN) and Probabilistic Neural Network (PNN). The criteria used for testing the used algorithm are maximum and minimum error rate for predicting performance of the students.

Results of ANN : The table 2 shows the performance of the conventional ANN towards the prediction of the students' performance from the collected information, the result shows due to the trial and error assignment of back propagation based learning strategy the error rate of this model is high with the MAX MRE value as 4.3, MMRE value as 0.44. The prediction accuracy on the specified range of values is 0.39 and 0.60 which are below average level.

Table 2: Performance of the Conventional Artificial Neural Network (ANN) Based on Student's Performance

	Measures			
Models Used	Max MRE	MMRE	Pred(0.15)	Pred(0.85)
ANN	4.31776	0.4384	0.3921	0.6032

Results of PNN : The table 3 shows the performance of the Probabilistic Neural Network (PNN) which performs the prediction of the students' academic performance and from result it is observed that the assigned of node weights using the probabilistic basis slightly improves the performance of the prediction system compared with ANN. The error rate of this model is low compared to ANN but fails the proposed system the MAX MRE value as 3.5, MMRE value as 0.41. The prediction accuracy on the specified range of values is 0.36 and 0.68 which are below average level.

Table 3: Performance of the Probabilistic Artificial Neural Network (PNN) Based on Students Performance

	Measures			
Models Used	Max MRE	MMRE	Pred(0.15)	Pred(0.85)
PNN	3.50690	0.4196	0.3693	0.6821

Results of EVANN: The table 4 shows the performance of proposed EVANN they used three different types of evaluation metrics are used in this simulation performance result. From the table it is observed that the Max MRE obtained by EVANN has the least error value while comparing the ANN and PNN.

Table 4: Performance of Proposed EVANN Method Based on Students Academic Performance

	Measures			
Models Used	Max MRE	MMRE	Pred(0.15)	Pred(0.85)
EVANN	2.01521	0.2158	0.8012	0.7843

The least error value obtained by this proposed work shows that its performance is higher in student's academic performance prediction of accurate outcomes. The MRE value is computed based on computing the difference between actual values of class attribute Result for each record is compared with the predicted outcome of the EVANN for each instances and dividing with the actual value. The maximum MRE value of each technique is compared and shown in the figure12.

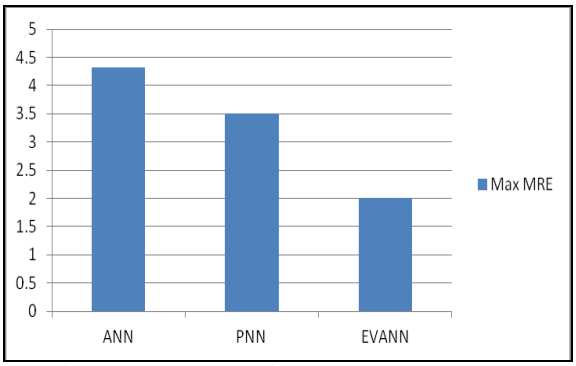


Fig. 9: Performance Comparison of Three Methods Using Maxmre Metric to Determine the Students' Academic Performance.

The proposed EVANN shows better performance by producing minimum error value next to that PANN holds the place and the worst case is produced by ANN. The Table 5 shows the Performance comparison of proposed NPSO with the other existing methods.

Table 5: Performance Comparison of Proposed NPSO with the Other Existing Methods

	Measures			
Models Used	Max MRE	MMRE	Pred(0.25)	Pred(0.75)
ANN	4.31776	0.4384	0.3921	0.6832
PNN	3.50690	0.4196	0.3693	0.6021
EVANN	2.01521	0.2158	0.8012	0.7843

In this work each instances of students dataset MRE values obtained from above mentioned formula is summed together for whole dataset and produces mean magnitude of relative error. The optimal search quality of the genetic algorithm with neural network optimized the prediction of Students academic performance analysis.

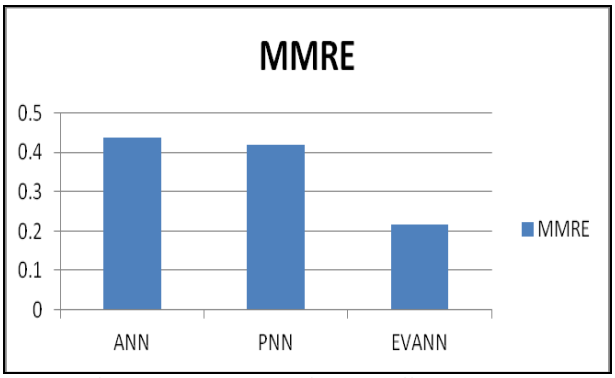


Fig. 10: Performance Comparison of Three Different Methods Based on the MMRE Metric.

The output of the result predicted by EVANN is compared with the actual output of the class attribute result for the given prediction value 0.15 and 0.85. The whole prediction values cannot be listed in this paper so running example for two prediction values are taken. The number of times the prediction value 0.15 and 0.85 produced by the proposed model is taken into the count and total number of instances is divided with that count.

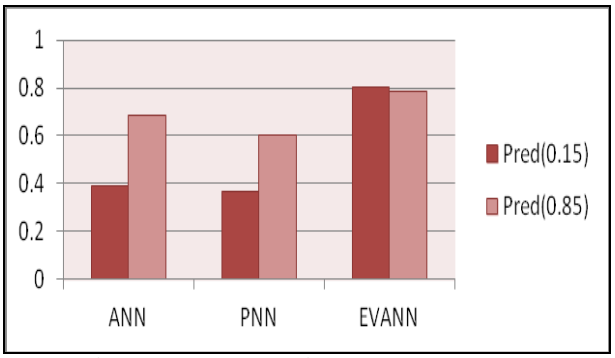


Fig. 11: Performance Comparison of the ANN, PNN and EVANN Using the Prediction Accuracy for Two Different Values.

The proposed model produces more number of correct prediction values than the other existing approaches because of its heuristic learning's and correcting technique.

This proposed research work aims at predicting the performance of the students of various colleges. The proposed work is developed based on the bio inspirational based approach for increasing the performance of prediction process. In general ANN or PNN assigns their weights on the basis of trial and error during the training phase. This proposed work utilized the knowledge of the genetic algorithm to assign the weights of the hidden nodes and thus its expected outcome and the actual outcome are greatly matched. Thus, the error rate of the proposed model is very low while comparing to other two existing algorithms, whilst the prediction accuracy is also greatly improvised.

6. Conclusion

In this research work, a prediction model based on the integrating genetic algorithm with artificial neural network is developed to contribute in the field of education data mining. The students' performance is first learned in the training phase with the instances and its class labels. During this phase the ANN model is trained by adjusting its initial random weights assigned to each node in the hidden layer to compute the appropriate output. After the initial setup the weights are modified with the help of the genetic algorithm where each population of instances is assigned with each node of the ANN. With the characteristics and the fitness function of the genetic algorithm it started finding the best weight values with the dependence of its fitness value the best among them has chosen and assigned. With support to the simulation result it is concluded that the optimized Evolutionary Artificial Neural Network contributes more accurate result than the other approaches used for comparison.

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