Predicting Student Performance in an ODL Environment: A Case Study Based on Microprocessor and Interface Course

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***Abstract*— The Open University of Sri Lanka adopts an Open and Distance Learning philosophy that breaks down many barriers for students to pursue their higher education dreams. One critical feature of Distance Learning is the onus on the students to be in charge of their learning. Academics and academic support staff facilitate this learning process by conducting many activities. But by the end of the course period the performance of students varies where some students get classes and others fail. The university has taken several steps to support learners while they are pursuing their degree programs, but the effectiveness of these initiatives is not as good as desired. In this project we propose a system of continuous monitoring of student's academic activities to build a dynamic profile of the student throughout the study program. The proposed system will analyze student activities continuously and will predict the future performance based on the student's own data as well as patterns identified by analyzing the data generated by previous students. The system will provide this information to the academic and academic support staff as well as the student so corrective action can be taken when a student is expected to perform badly in future activities. The system uses an Artificial Neural Network (ANN) model for predicting the performance of the student and this model can predict the students' performance in accuracy of 93.7.**

Keywords*— *Artificial Neural Network (ANN), Learning Analytics, Deep Learning, Learner Support

I. INTRODUCTION

The Open University of Sri Lanka uses Open and Distance Learning (ODL) methodology to conduct its academic programs. ODL approach removes barriers to open education and provides flexible learning opportunities to anyone, anywhere, any time and at any pace. It has been using a practice that is recently named, the "flipped classroom model" since its inception. Students are provided learning material at registration that they study on their own. Their learning process is supported through a series of day schools, lab classes, field trips and other face to face activities. Their progress is continuously evaluated through Tutor Marked Assignments (TMAs), LAB evaluations, Continuous Assessment Tests (CATs), Mini projects, viva and other forms of formative evaluation often culminating in a summative evaluation in the form of a final examination or a final viva. In an ODL system, the distance between the learners and the facilitators is also a challenge that needs to be addressed. Due to the distance there is a lack of opportunity for facilitators to observe the academic progress of the students continuously and make necessary course corrections to ensure academic success. This is due to the lack of a proper system to continuously monitor and analyze student performances, thus providing the academics an opportunity to intervene to improve the situation based on actual data. Only a few milestone assessments are carried out and the overall performance is often measured through a final examination. This creates a situation which leads to low completion rates, because by the time the results of the examinations are known it is too late to take any action to improve the situation. It is known that continuous motivation is essential for a student's success in an ODL environment. Often, the students whose performance is low in formative assessments dropout of their studies taking the easy way out. Thus, it is important for an institute working on ODL mode to devise a mechanism to continuously monitor the student performance and carry out remedial actions when the student is not faring or expected to fare well in their studies. Therefore, we need a better solution to increase the output of the university.

In this paper we describe a system for predicting student performance using deep learning technology. Using this system, a student's activities are regularly monitored and evaluated based on the current values of a set of identified parameters as well as historic data. The output is a prediction of the students' performance in the future. This data will be useful to the students as well as academics to make necessary changes to increase the chances of academic success. We can analyze the performance of the student by considering the various factors of the students. Some of these factors include attendance of the lectures, marks of the TMAs, marks of the CATs, marks of the presentation, and marks of the Labs etc. University could identify the factors for low performance earlier and is able to predict students' behavior. This knowledge can help them in taking proactive actions, to improve the performance of such students. Students will be able to identify their weaknesses beforehand and can improve themselves. Lecturers will be able to plan their lectures as per the needs of students and can provide better guidance to such students.

II. LITERATURE REVIEW

Many systems were implemented in the industry to perform student profiling and data mining. Some of them are just student management systems and others are predicting/ data mining systems. This section summarizes the different works that have been done related to this area.

S. Naser and his colleagues published a paper in the title of "Predicting Student Performance Using Artificial Neural Network: in the Faculty of Engineering and Information Technology". Their work describes the

predicting performance of a sophomore student enrolled in engineering majors. A number of factors have been identified that may possibly influence the performance of a student. The aims of this study are identify some suitable factors that affect a student performance, convert these factors into forms appropriate for an adaptive system coding and model an Artificial Neural Network that can be used to predict a student performance based on some predetermined data for a given student. Input variables have been identified which can simply be obtained from the student file and registrar system. The input variables are High School Score, Results in Math I in the student freshman year, Results in Math II in the student freshman year, Results in Electrical Circuits in the student freshman year, Results in Electronics I in the student freshman year, CGPA of the freshman year, Type of high school whether it is in Palestine or outside and Student gender [1]

Thakar and Mehta, try to understand the behavior of the students, and try to solve the problem of student turnover and unemployed students in their paper "Performance Analysis and Prediction in Educational Data Mining [2]. This is a survey paper. They have summarized many paper details. Their stakeholders are universities/institute, management, teachers, students, parents. They analyze and predict with the help of data mining techniques. Such as Neural Network, Decision tree, K-means clustering, Association Rule Mining.

Thakar and Mehta work (2018) describing the Predicting students' results in higher education using a neural network**.** They were observed the poor quality of graduates of some Nigerian Universities in recent times. It has been partly traced to inadequacies of the National University Admission Examination System. In this study an Artificial Neural Network (ANN) model, for predicting the likely performance of a candidate being considered for admission into the university was developed and tested. Various factors that may likely influence the performance of a student were identified. Such factors used as input variables for the ANN model. Their model uses a Neural Network with one input layer, two hidden layers and one output layer. The following factors were used as input features. Type of study program (distance education /part time or full time education), Gender of the student, High-School graduation GPA, Age of the student and Difference in years from the moment the student graduates high-school until he/ she enrolls at university. They classified students according to students GPA after the first year of study in three classes:

POOR RESULTS (those students with GPA lower than 6), MEDIUM RESULTS (those students with GPA between 6 and 8) and GOOD RESULTS (those students with GPA greater than 8). [3]

P Jain and his group describe their study in an Artificial Intelligence-Based Student Learning Evaluation conference paper. They aim to discover the knowledge for analysis student motivation behaviour on e-Learning based on Data Mining Techniques, in case of the Information Technology for Communication and Learning Course at Suan Sunandha Rajabhat University. The data mining techniques were applied in this research including association rules, classification techniques.[4]

D. Kabakchieva was studied Mining Educational Data to Analyze the Student Motivation Behavior. His study presents the results from data mining research, performed at one of the famous and prestigious Bulgarian universities, with the main goal to reveal the high potential of data mining applications for university management and to contribute to more efficient university enrolment campaigns and to attract the most desirable students. The research is focused on the development of data mining models for predicting student performance, based on their personal, pre-university and university-performance characteristics. The dataset used for the research purposes includes data about students admitted to the university in three consecutive years. [5]

III. Artificial Neural Network

An Artificial Neural Network (ANN) is a mathematical model that tries to simulate the structure and functionalities of biological neural networks. Basic building block of every artificial neural network is an artificial neuron, which is a simple mathematical model. The brain is a highly complex, nonlinear and parallel information processing system that has the capability of organizing neurons so as to perform certain computations. It is many times faster than the fastest digital computer. A neural network contains an interrelated set of artificial neurons and it processes information using a connectionist form to computation. A Neural Network can model and it can train a model in nonlinear and very complex relationships which is most important because the relationship between inputs and outputs are nonlinear as well very complex. After learning from the initial inputs and their relationships, it can infer unseen relationships on unseen data as well. And it does not impose any restriction on the input features. We can use data with high volatility.

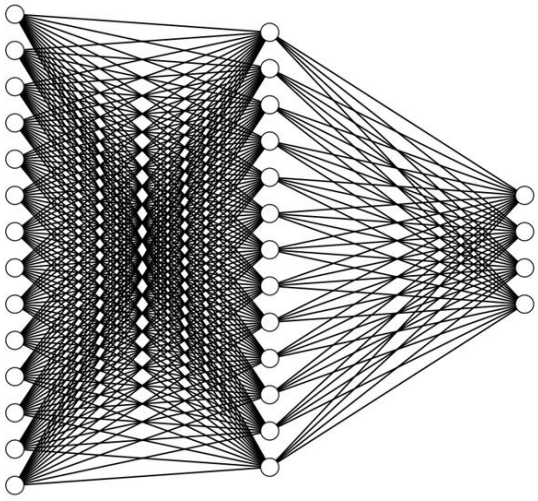

Figure 1 Neural Network Diagram

An Artificial Neural Network emulates the human brain in solving a problem, is a more common approach that can tackle this kind of problem. A Neural Network will take the input data and push them into an ensemble of layers. The network needs to evaluate its performance with a loss function. The loss function gives to the network an idea of the path it needs to take before it masters the

knowledge. The network needs to improve its knowledge with the help of an optimizer.

A. Input Variable

In order to model student performances it is important to identify the correct parameters that will provide an insight into the students' performance. The following were used to identify a set of parameters as input to our model.

Studying the research papers which are most related to this topic area and the technologies

Distributing the questionnaire among the students who are currently following the degree program

Studying of the academic model used by the Open University of Sri Lanka.

IN order to test our hypothesis, the model was developed for the Microprocessor and Interfaces course. This course is done by many students who follow BTech Engineering degree program as a compulsory course. It was also noted that the number of students who get eligible for the final examination as well as those who pass the exam is comparatively less than other similar courses. Thus, the course presented itself as an ideal choice where a prediction on the student performances can make a great difference in the success rate of the students. We selected 14 genetic and non-genetic factors according to the particular course structure. A description of the importance of each factor is described at continuation.

Open University consists of an ODL system. Therefore, the students who are following the degree program have to put a huge effort to study. In the "flipped classroom model", students study the learning material at their leisure, hence attending the Day Schools and the LAB session takes a very important role. Because they can discuss the concepts they have learnt during their studies directly with the lecturer and understand how these concepts are applied in practice under the guidance of the lecturer. Lab classes allow them to have hands-on experience. These two activities have a big impact in their learning process. TMA, LAB, CAT marks measure the students' performance during the course. These are formative assessments that allow the student and the academic conducting the course to have an idea how the student is progressing in his academic work. A student use of Library facilities gives an indication of the learning process of the student as it indicates that the students are delving deeper into the subject matter. Using the university's student portal named MyOUSL and ELearn facilities students share knowledge with peers and they can interact asynchronously with the lecturer to clarify their doubles or have a meaningful discussion on the material being studied. Participation in activities organized by different societies and in sports events is an indication of the wholesome experience that the student is enjoying at the university. Further, often these activities are organized with sponsorships from companies giving the students a first-hand opportunity to interact with representatives of these companies and become aware of new trends and technologies. Studies have shown that exercise increases blood flow to the brain and helps the body build more connections between nerves, leading to increased concentration, enhanced memory, stimulated creativity and better developed problem solving skills [11]. In short, playing sports helps everyone's brain grow and makes it work better. We have used a model to study how these factors affect the students' performance.

In summary, we have identified the following features as inputs to the model.

1. Day School Attendance
2. Lab Attendance
3. TMA1 Marks
4. TMA2 Marks
5. TMA3 Marks
6. LAB1 Marks
7. LAB2 Marks
8. LAB3 Marks
9. CAT Marks
10. Using Library Facilities
11. Using My OUSL Facilities
12. Using ELearn Facilities
13. Interaction with Society
14. Participation of Sport

Above input factors were converted into a format that can be used in the Neural Network Analysis. Table 01 shows the transformation for all 14 input features.

Table 1 Transformation of input data

No	Input Variable	Domain	
01	Day School Attendance	1 2 3 None (No of days)	1 2 3 4
02	Lab Attendance	1 2 3 None (No of days)	1 2 3 4
03	TMA1 Marks	Above 80% 60 – 79 40 – 59 0 – 40	1 2 3 4
04	TMA2 Marks		
05	TMA3 Marks		
06	LAB1 Marks		
07	LAB2 Marks		
08	LAB3 Marks		
09	CAT Marks		
10	Using Library Facilities (per week)	More than 20 h 15 – 20 07 – 15 0 – 07	1 2 3 4
11	Using My OUSL Facilities (per week)		
12	Using ELearn Facilities (per week)		
13	Interaction with Society (per week)		
14	Participation of Sports (per week)		

B. Output Variable

In our model, the output variable represents the student's academic performance. Output variables were categorized into four categories as “Excellent”, “Good”, “Moderate” and “Weak”.

IV. METHODOLOGY

Artificial Neural Network is an algorithm that uses past data to train a model. It can learn from the training data. Using the ANN trained using historical data, it is possible to produce an output which is the predicted performance of a new student. Neural Network can model and train a model in non-linear and in very complex relationships. And it does not impose any restriction on the input variables. Therefore, we can decide the number of inputs and features according to our study. Further Neural Network can model with high volatility. Our Model uses three layers as follows: 14 neurons are used in the input layer and 13 neurons in the hidden layer with and 4 output neurons in the output layer. The Neural Network activation function is responsible for transforming the summed weighted input from the nodes into the output for that input. “ReLU” function was used as activation function of input layer and hidden layer and “Softmax” function was used as activation function of output layer. Inputs are processed using the above functions to produce the desired output. "ReLU" function can converge network very quickly and the “Softmax” activation function is used for the output layer and when we categorize our inputs into multiple categories.

The model also used feed forward back propagation algorithms for training the data set. ”Adam” is used as an optimizer. Because it shapes and mold our model into its most accurate possible form by futzing with the weights.

A. Dataset

Since this is a faculty course most of the students are registered for these selected courses. 1068 records from the last three years student’s data were used for the purpose of training and testing. 907 samples were used to train the model and 161 samples were used to validate the model.

B. Implementation

The system was developed as a web based system. Frontend of the system was created using PHP, HTML and all data stored in the MySQL database. A GUI was built to collect student information as well as to display their profiles and to display their performance level. “TensorFlow” framework was used to create the neural network model. Python is used as the language to build a neural network.

The Model was created and trained using the historical data (2016 - 2018). Once the model was trained, new students can enter their data to the system to view predicted performance as the output. When a student enters the data, the output is also communicated to the academic in charge of the course. The process following to build the ANN system is shown in Fig 2.

C. Technologies Used to build the system

TensorFlow: TensorFlow is an end to end open source platform for machine learning. It is a free and open source software library for dataflow and differentiable programming across a range of tasks. It is a symbolic math library and is also used for machine learning applications such as neural networks. [7]

Pandas: This is a software library written for the python programming language for data manipulation and analysis. Pandas library is supported in the TensorFlow environment. It is a data structure and data analysis tool for python programming. [8]

Keras: Keras is an open source neural network library written in python programming language. It is capable of running on the TensorFlow. It is designed to enable fast experimentation in neural networks. [9]

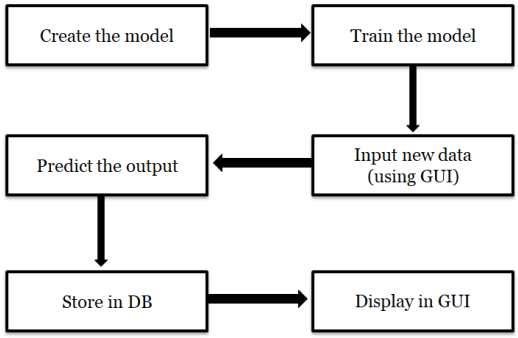

Figure 2 Describe the system overview

V. RESULT AND DISCUSSION

As explained in section 4, the model used in this work consists of three layers. Input layer has 14 neurons, the hidden layer has 13 neurons and the output layer has 4 neurons. Input layer and hidden layer use the "ReLU" activation function and output layer uses "Softmax" activation function. Fig 3 shows the script used to configure the model.

```
#model configuration.
model = Sequential()
model.add(Dense(14, activation='relu',  kernel_regularizer=regularizers.l2(0.001),input_shape = (14,)))
model.add(Dense(13, kernel_regularizer=regularizers.l2(0.001), activation='relu'))
model.add(Dense(4,  kernel_regularizer=regularizers.l2(0.001),activation='softmax'))
model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
history  = model.fit(x_train,y_train, epochs = 200, batch_size = 5, validation_data = (x_test,y_test))
model.save('Model_A.h5')
```

Figure 3 Script of Configuration

Fig 4 shows the number of interconnections between different layers of the model. It consists of dense layers which are the deeply connected neural network layers that is the most common and frequently used layer. It performs the following operations on the input and return output.

output = activation(dot(input, kernel) + bias) (1)

input - input data

activation - activation function

dot - numpy dot product of all inputs and its corresponding weights

kernel - weight data

bias - biased value in machine learning to optimize the model

In the model, the summary displays the following information.

The layers and their order in the model.

The output shape of each layer.

The number of parameters (weights) in each layer.

The total number of parameters (weights) in the model

Using the "Keras Library" we can show whether neural network parameters are trained or not. In order to calculate

```
Layer (type)                 Output Shape              Param #
=================================================================
dense_1 (Dense)              (None, 14)                210
_________________________________________________________________
dense_2 (Dense)              (None, 13)                195
_________________________________________________________________
dense_3 (Dense)              (None, 4)                 56
=================================================================
Total params: 461
Trainable params: 461
Non-trainable params: 0
```

Fig. 4. Summary output of the model

the number of parameters within an individual layer we need the following data:

Number of inputs to the layer

Number of output from the layer

Whether or not the layer contains biases

The output is calculated as

$$Z = XiWi + b \quad (2)$$

\Where

Xi - Value of input parameters

Wi - Weight of the parameters

b - bias

To calculate the number of parameters, the number of inputs to the layer is multiplied by the number of outputs from the layer and the number of biases in the layer added to the result. According to the calculation, input layer has 210 (14*14+14) parameters. Hidden layer has 195 (14*13+13) parameters. And output layer has 56 (13*4+4) parameters. This model has 461 total parameters. We used the "model.fit()" method of Keras library to train the parameters using historical data as shown in Fig 3. The summary output produced by the "model.summary()" method as shown in Fig4. In Fig4 dense_1, dense_2, dense_3 are input, hidden, output layers respectively. In the code output shape (None, 14) indicates whether we have a pre-defined number or not and corresponding output to the next layer.

We use a confusion matrix to lay out how many predicted categories or classes were correctly predicted and how many were not. It allows the visualization of the performance of an algorithm. It produces predicted values in this case, the student's future performance only by looking at the input value as a matrix. The X axis represents the "Predicted Values" and the Y axis represents the "True Values". Diagonal describes the values which model has predicted correctly. Values outside the diagonal represent the values which were predicted incorrectly. When we run our model the system produces the confusion matrix in Jupyter Notebook using Tensorflow Environment. In this model, the Confusion matrix used 161 test data from the total data set of 1068 values as described in section 4.1. Among the 161 test data 151 data were predicted correctly. Correctly predicted values are displayed along the diagonal. Ten values are outliers

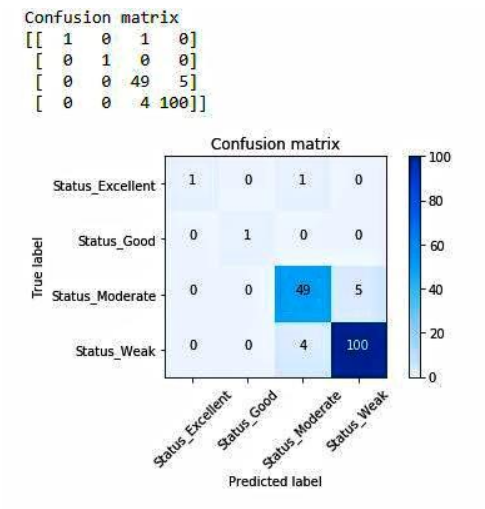

Figure 5 Confusion matrix for the model

Fig 6 represents the validation and training accuracy of the model. Y – Axis represent the accuracy level and the X – Axis represent the number of Epochs. Training accuracy is the fraction of predictions the model got correct using training data. Validation accuracy is the fraction of prediction the model got correct using testing data. Training accuracy is displayed using the "dotted line" (blue color) and validation accuracy is displayed using the "line" (red color). 200 epochs were used to the system. It displays the variation of the accuracy for each epoch. As shown in Fig 6 in between 0- 25 epochs, training accuracy and validation accuracy increased very quickly. Between 25 - 50 epochs, accuracy slowly increased. Then up to 200 epochs accuracy remains steady with a little variation around 93% accuracy level. Thus, the graph shows that beyond 50 epochs the model displays a high accuracy in both training and validation. We can consider that the model can be used to predict student performance with a high accuracy.

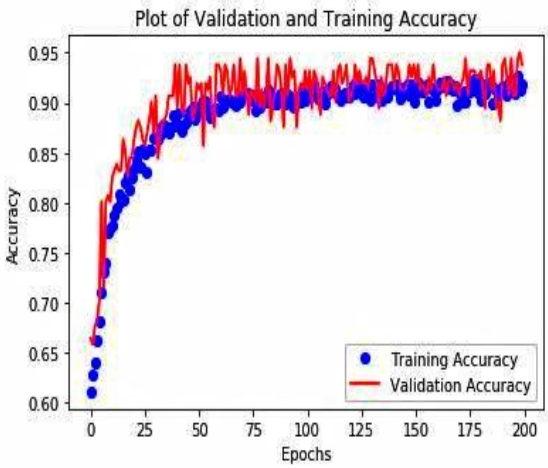

Figure 6 Plot of the Validation and Training Loss

Fig 7 represents the validation and training loss. Y – Axis represent the loss level and the X – Axis represent the number of Epochs. Training loss is nothing but a prediction error of a neural network using training data. Validation loss is a number indicating how bad the model prediction using test data. Training loss is displayed using the "dotted line" (blue color) and validation loss is displayed using the "line" (red color). Between 0 - 25 epochs, training and validation loss rapidly decreases. Between 25 - 75 epochs, loss reduces slowly. Up to 200 epochs, loss decreases very slowly. According to this graph model loss is very low. This collaborates that the accuracy of prediction using our model is high.

Samples of testing dataset which are used as model inputs are shown in Fig 8 and respective outputs which are extracted from the test dataset are shown in Fig 9. These are randomly selected data from the test dataset. Fig 10 shows the results which are predicted by the model for corresponding inputs which are shown in Fig 8. When comparing Fig 9 and Fig 10 it clearly shows the success of this model. Because actual outputs and the predicted outputs are the same for the used input factors. It is proof that the model can predict the student performance in a very accurate manner.

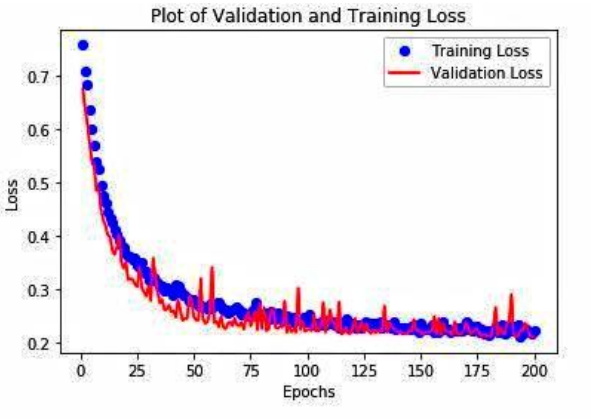

Figure 7 Plot of the Validation and Training Accuracy

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can say that this model can predict the students'

	Day_Scl_Attendance	Lab_Attendance	TMA1	TMA2	TMA3	LAB1	LAB2	LAB3	CAT	Library_Facilities	My_OUSL_Login	ELearn_Login	Society	Sports
260	4	4	4	4	4	4	4	4	4	4	4	4	4	4
569	4	3	2	4	4	3	3	3	4	3	3	3	3	3
529	4	4	4	4	4	4	4	4	4	4	4	4	4	4
10	3	2	2	2	3	2	2	2	4	2	2	2	2	2

Figure 8 Sample input data from test dataset

	Grade_Excellent	Grade_Good	Grade_Moderate	Grade_Weak
260	0	0	0	1
569	0	0	1	0
529	0	0	0	1
10	0	1	0	0
111	0	0	1	0

Fig. 9. Sample output data from test dataset

```
260  Student Input:= [[4 4 4 4 4 4 4 4 4 4 4 4 4 4 4]]
Student Status:= ['Weak']
569  Student Input:= [[4 3 2 4 4 3 3 3 4 3 3 3 3 3]]
Student Status:= ['Moderate']
529  Student Input:= [[4 4 4 4 4 4 4 4 4 4 4 4 4 4]]
Student Status:= ['Weak']
10  Student Input:= [[3 2 2 2 3 2 2 2 4 2 2 2 2 2]]
Student Status:= ['Good']
111  Student Input:= [[4 3 3 3 4 3 3 3 4 3 3 3 3 3]]
Student Status:= ['Moderate']
```

Fig. 10. Predicted results by the model

VI. Conclusion

In this paper we have described a system based on Artificial Neural Networks to predict students' performance during a course. 14 parameters that are considered as important for a students' success in a course are used as the inputs and depending on the values future performance of a student was predicted. First of all we gathered student details. Then preprocessed the data to identify the data set consisting of any non-unique values and non-applicable values. Then the model was created by using the Neural Network Algorithm. Data set was divided into two parts as training data and testing data. Model was trained using training data and tested by using test data. Model summary was generated by using the "Keras". Then the confusion matrix was plotted for better visualization of the test data behavior. Two important graphs were plotted to display the accuracy and the loss when we train and test the model using training data and the testing data. Using these two graphs we can clearly see how this model varies for each epoch. According to the model summary, confusion matrix and the accuracy and loss graph clearly display the success of our model. In mathematically we can say that this model can predict the students' performance in accuracy of 93.7.

We do not use pre-enrollment data in the system, but have identified that they can have a strong relationship to how a student will perform in the course. The next version of the system will incorporate pre-enrollment parameters such as the demography, social status, performance at school level exams, and language proficiency as input parameters. The system can be used by the students as well as academics in charge of the courses to assess a student's predicted performance. This would provide an opportunity for both the student and the academic to take corrective action if the student is expected to perform badly. Through this system, students with academic problems can be identified early and course corrections applied to change their performance from weak to excellent.

In conclusion we have built a system that can improve the success rates of students following study programs in Open and Distance Learning mode through continuous monitoring and predicting future performance. The system can be used by students themselves and academic staff to improve completion rates for ODL students based on the predicted values we plan to link the system to the universities managed information system. Evaluation can be done automatically. Once done on a continuous activity throughout the student's academic career

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