Levenberg-Marquardt Algorithm Based Neural Network Model for Predicting Correlation Course Performance of Mechanical Engineering Students

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Highlights

- The generated model recorded an r Coefficient value of 0.96085, Mean Squared Error (MSE) of 0.017% and Mean Absolute Percentage Error (MAPE) of 20% which is considered satisfactory.
- Chemistry 2 and Physics got the highest relative importance percentage while Calculus 1 is the lowest.
- Enhancement and tutorial classes are recommended for subjects Chemistry and Physics

Abstract

The onset of the pandemic becomes more challenging to the academic departments especially those programs with board examinations. The difficulty in learning during the online setup had questioned the quality of teaching and learning. The Mechanical department of FEU Institute of Technology had experienced fluctuations in the passing percentage during the board examination administered during the pandemic period. The use of artificial intelligence is proliferating in research, the Artificial Neural Network (ANN) algorithm has become an advanced tool when it comes to building of performance models. This study utilizes ANN using MATLAB to create a model that can predict the performance of Mechanical Engineering students in the Correlation 1 subject. Employing educational data mining techniques, the ANN model output could identify the student's performance. The ANN models utilized Feed – Forward Back Propagation and Levenberg-Marquardt algorithm due to its simplicity and wide array of use. The utilization of the samples was distributed into three phases: training, validation, and testing phase. Correlation 1 grades of the students enrolled during the third term of SY2021-2022 were included in the analysis. The input parameters were the student's academic performance in the ten (10) subjects prior to the correlation 1. The output variable used in modelling is the respondents' academic performance in the correlation 1 subject. From the data gathered, the model generated is satisfactory based on the high correlation values and low error with r coefficient value of 0.96085, Mean Squared Error (MSE) of 0.017% and Mean Absolute Percentage Error (MAPE) of 20%. Higher Education Institutions (HEIs) will be guided in determining the student's predicted performance and to carry out measures to give priority to the low performers. The identified Mechanical Engineering students should be given higher priority during the conduct of enhancement classes. The early prediction data can help the Mechanical department to implement solution to improve the actual performance of the students in correlation subjects. Using the output models, the students can easily identify their predicted academic performance integrating their academic records and likely will give them proper motivation to improve.

Key Words: academic performance, artificial neural network, correlation, Mechanical Engineering; prediction model

1. Introduction

The Corona Virus Disease (COVID-19) in the Philippines had severely impacted the educational set-up changing the mode of classes to online (Dy et. al, 2021). For the past two (2) years of the pandemic, different teaching pedagogies were utilized on different academic institutions and finding solutions on how the learning environment becomes more effective while classes is rendered online. In Mechanical Engineering, it becomes a challenge, since most of the courses offered in the Mechanical Engineering program are board examination subjects. This difficulty is being experienced in the Mechanical Engineering department of Far Eastern University (FEU) Institute of Technology. Aside from revisiting its learning management system (LMS), different teaching methods were used by each of the professors depending on the level of difficulty of the subject. The pandemic situation has caused many changes in the education sector worldwide and each of the academic institutions should adapt to the need of time using the online or hybrid modality of learning. However, international studies have concluded that this modality has affected the academic performance of students (Vargas-Ramos et. al, 2021).

The use of prediction models for academic performance have become an advanced tool in analyzing students' behavior in their academics. This study focuses to build a model using Artificial Neural Network (ANN) using Matrix Laboratory (MATLAB) to predict the likelihood of Mechanical Engineering students to pass the correlation courses. The ANN model output could identify the student's performance in the correlation subject in Mechanical Engineering employing educational data mining techniques through the academic performance of students. Students enrolled in the subject correlation 1 during the third term of SY2021-2022 were included in the study. The input parameters were the student's academic performance in the different subjects prior to the correlation course. The Correlation 1 course is a subject in the Mechanical Engineering department that covers all basic mathematics and science subjects the first-year level. The subject outline is patterned from the board examination, and it is a review of all the mathematics and sciences subjects. The use of ANN in the present study uses the Levenberg-Marquardt Algorithm in generating the model and the Garson's algorithm to calculate the relative importance percentage. The output model will be useful to the Mechanical Engineering department in conceptualizing measures to improve the academic performance of the students.

Determining the student's predicted performance will help Higher Education Institutions (HEI) to carry out measures that will give priority to those who will be predicted as low performers. The identified Mechanical Engineering students should be given higher priority during the conduct of enhancement classes of correlation courses. Due to the early prediction, institutions can implement solutions and expect better academic performance. Using the output models, the students can easily view their predicted academic performance integrating their grades of the subjects before they took the correlation 1 subject. The HEI can utilize the model to identify measures in which the teaching and learning environment can be enhanced to improve the students' academic performance. Thus, the generation of prediction models through artificial neural networks can be of great help in the prediction of low performers in the subject correlation. The use of artificial intelligence techniques using neural networks become useful in assessing what intervention measures that the academic department should implement to increase the possibility of having aa higher passing percentage.

The academic achievement of students in their tertiary education in the Philippines is a key factor in their life. Taberdo and Taberdo (2018) state that the student's academic performance may help as a tool to evaluate the quality of education that the HEI can offer. Far Eastern University Institute of Technology (FEU Tech) Mechanical Engineering department acts as a medium to bridge the students towards their attainment of being licensed Mechanical Engineers. Aside from the major subjects that the university offers,

additional subjects on correlations courses were introduced to cater the needs of refreshing and reviewing the past subjects that were taken since their first year until their terminal year. Predicting the students' performance at high accuracy level during the period of their academic years becomes significant for which the institution can easily identify the strong and weak performers, as early as possible. In this case, the institution can lend additional support and mitigate measures that would enhance further the academic performance of the students at the moment that their performance has been predicted. For the faculty handling major subjects, early prediction of level of performance could be considered important in terms of improving the level of teaching and learning factors. The study of Taberdo (2018) concluded that teaching and learning process is a two-way communication and emphasizing the importance of the role of teachers.

Artificial Neural Network (ANN) is a statistical learning algorithm that is utilized to generate and create prediction models. ANN mimics the function of human brain therefore, it needs to learn or to be trained based on the training set that contains associated neurons in the form of weights and biases which calculate a predicted output values from the input parameters (Concha, and Dadios, 2015). The study of Livieris, Drakopoulou and Pintelas (2017), has concluded that "MSP-trained neural networks exhibit more consistent behavior and illustrate better classification results than the other classifiers", to which is tested in predicting the performance of the first-year students in Mathematics. The present study utilizes the Artificial Neural Networks (ANN) with the aid of MATLAB in the prediction modelling process. The Levenberg-Marquardt algorithm was used and is considered fitting to the purpose of the study since the algorithm is specifically intended to loss functions in terms of sum of squared errors (Poso and de Jesus, 2020).

2. Methods

2.1 The data

There are 42 students who are included in the study who enrolled the subject Correlation 1 (ME0013) last third term of SY2021-2022. The 42 students are all Mechanical Engineering students at FEU Institute of Technology. The were gathered from the registrar's records of the 42 students identified.

2.2 Data gathering

The academic performance or the grades in ME0013 were gathered from the registrar's system as the output variable. The input variables are the grades of the students of their previous subjects before the correlation 1 subject. The subjects are Mathematics 1 (COE0001), Mathematics 2 (COE0003), Chemistry 1 (COE0005), Physics 1 (COE0009), Chemistry 2 (COE0017), Calculus 1 (COE0007), Data Analysis (COE0011), Calculus 2 (COE0013), Physics (COE0015), and Differential Equation (COE0019). The data gathered are considered continuous data which are the grades of the identified students in the subject ME0013. The input data are the grades from the mathematics and science subjects taken by the students in their first-year level which are also part of the topic outline of the Correlation 1 course. Correlation 1 subject is a review course in which the topics are patterned from the board examination.

2.3 Artificial Neural Network

The ANN models utilized Feed – Forward Back Propagation Algorithm due to its simplicity and wide array of use. The topology of ANN models typically comprises of input layer, hidden layer containing hidden neurons and an output layer. The design criteria of the ANN are based on the following parameters: the training algorithm, adaptation learning function, performance function, hidden layers and hidden neurons,

weights and biases and transfer function. The summary of the design criteria of the ANN models in this study is shown in Table 1.

Table 1. The Design Criteria of ANN Models

Parameter	Value
Training Algorithm	Levenberg – Marquardt Algorithm
Adaptation Learning Function	Gradient Descent with Momentum Weight and Bias Learning Function
Performance Function	Mean Squared Error (MSE), Pearson Correlation Coefficient (R)
Number of Hidden Layers	1
Number of Hidden Neurons per Hidden Layer	3 to 10
Transfer Function	Hyperbolic Tangent Sigmoid (Tansig); Logistic Sigmoid (Logsig)

The study utilized Matrix Laboratory (MATLAB) R2018a neural network toolbox for modelling and simulation of the data. The researchers used the Levenberg-Marquardt algorithm. The utilization of the samples was distributed into three phases: training, validation and testing phase. The distribution of samples to generate the model is 70% for the training phase, 15% for the validation phase and 15% for the testing phase. The models that were derived to predict the performance of the students in the Mechanical Engineering correlation course is based on their academic performance in school.

The overview of the architecture of the ANN model derived from the MATLAB neural network toolbox is shown in Fig. 1. It shows the number of input parameters used to create the network, the number of hidden neurons in the hidden layer and the output layer of the generated model.

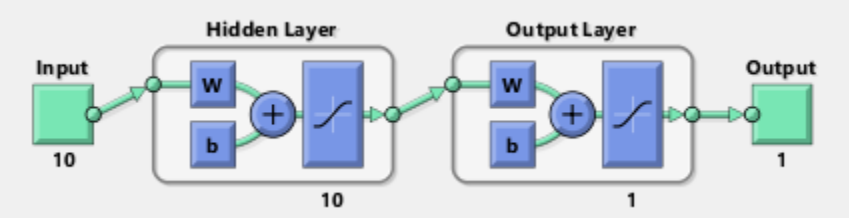

Figure 1. Overview of the Architecture of the Governing Model

The model has input parameters on the students' final grades retrieved from the Registrar's records. For the selection of the best model, the researchers used the highest R validation value and lowest MSE as the primary criteria for the selection of the model (Poso and De Jesus, 2022). Furthermore, as an additional criterion for the selection of the model, the percent error (% error) between the actual and predicted grades were used to select the best model.

2.4 Relative Importance (RI)

The Relative Importance (RI) of the input parameters was evaluated using a Machine Learning – based sensitivity analysis approach. The Garson's Algorithm (GA) was employed by utilizing the connection weights generated from the backpropagation ANN simulation of the input parameters. The factors that were taken into consideration are the academic grades on the subjects taken by the students prior to the Correlation 1 course. The results of the weights in the ANN were used in the evaluation of RI using the Gas approach.

3. Results and discussion

3.1 Simulation Results

Figure 2 presents the simulation results of the model. Different transfer functions were simulated (tansig, logsig and purelin) ranging from 3 to 10 hidden neurons. For the correlation model generated, the best model was attained from simulation using tansig function, 10 Hidden Neurons with Pearson's Correlation Coefficient (Rall) value of 0.96085, Mean Squared Error (MSE) of 0.017% and Mean Absolute Percentage Error (MAPE) of 20%.

The model demonstrated significantly high correlation results and low mean squared error as shown in Figures 2 and 3. The findings imply that the prediction model generated is highly satisfactory and it can be used by the Mechanical Engineering department in predicting the academic performance of the students who will take the Correlation 1 subject. Identifying the low performers could help the department in taking remedial measures such as enhancement classes or tutorials to the identified low performers.

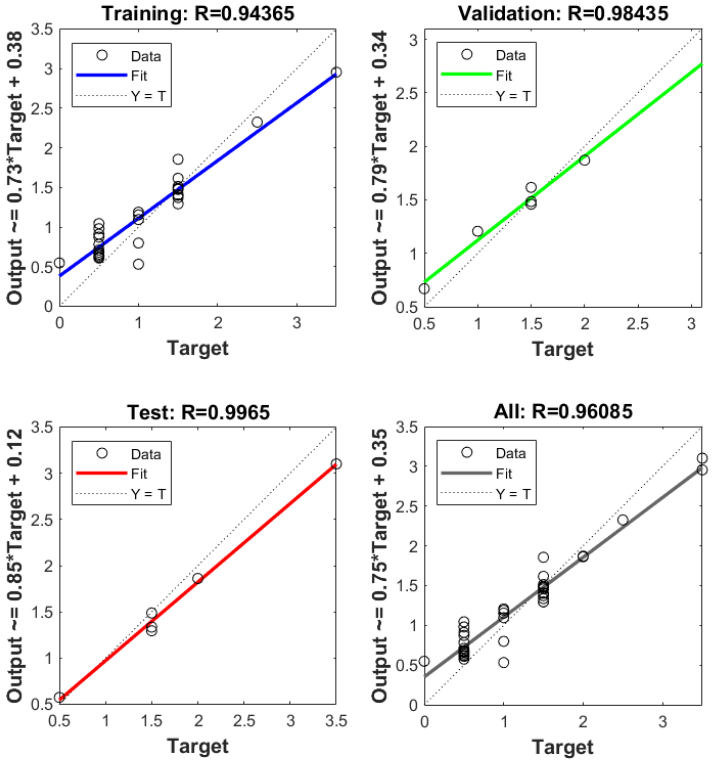

Figure 2. Correlation Plots for each Phases of Model Development

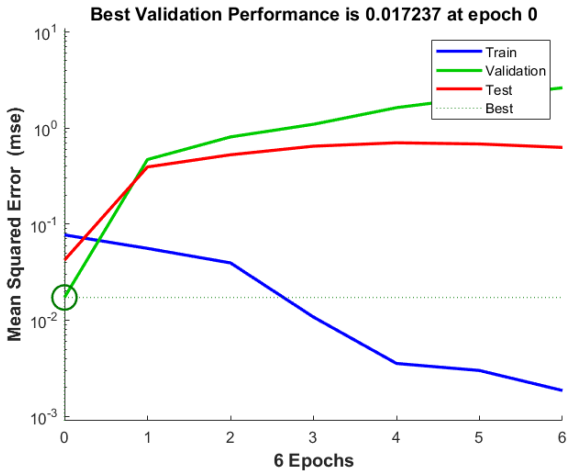

Figure 3. Performance and Mean Squared Error for the Model

3.2 Relative Importance

Table 2 and Figure 4 present the relative importance of the input parameters. Among the ten (10) subjects, Chemistry 2 (COE0017) got the highest relative importance percentage of 11.7082% followed by Physics

1 (COE009) with 11.0828%. The lowest relative importance percentage was recorded in the subject Calculus 1 (COE0007) with 8.2059%. Although there are discrepancies in the relative importance percentages values, the table reveals that the differences are insignificant, showing that all the 10 subjects prior to taking of the ME correlation 1 are of important subjects that can be considered in passing the ME correlation 1 course. This data implies that all the subjects considered in the input variables should be given importance by the course advisers to ensure good performance in correlation subjects. Based on the data, Chemistry and Physics should be given high importance in conducting enhancement classes or tutorial sessions especially to those predicted low performers. At present the department are conducting enhancement activities through its iCARE platform both in an online and f2f set up.

Table 2. Relative Importance Percentage

Subjects	**COE 0001**	**COE 0003**	**COE 0005**	**COE 0009**	**COE 0017**	**COE 0007**	**COE 0011**	**COE 0013**	**COE 0015**	**COE 0019**
Relative Importance %	9.6709	9.5782	9.7387	11.0828	11.7082	8.2059	10.034	10.320	9.075	10.585

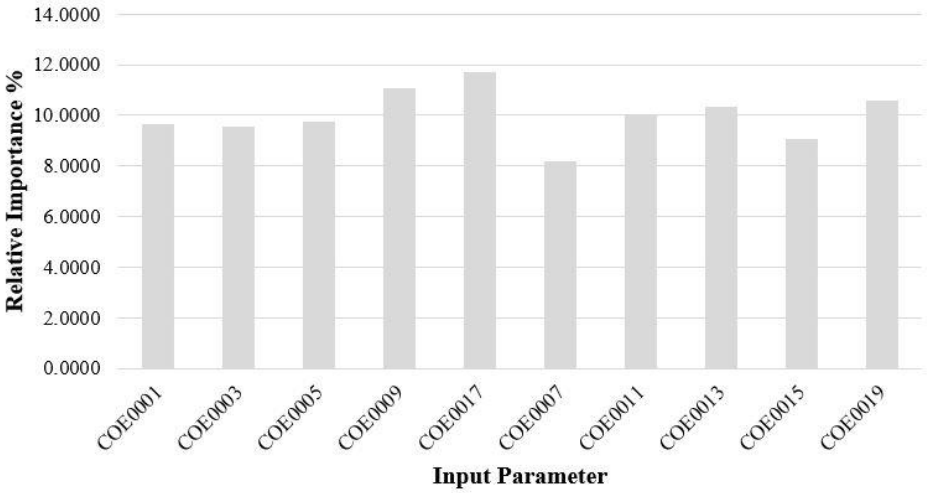

Figure 4. Relative Importance

4. Conclusions

The researchers had developed prediction models to forecast the performance of the students in the Mechanical Engineering correlation 1 subject (ME0013) based on their academic performance in different subjects prior to taking of the correlation course. The model has shown significant and high correlation results and minimal errors. It can be concluded, that based on the output models, the MatLab Neural Network Toolbox is very efficient in the prediction modelling using ANN. Therefore, it is recommended that the output models can be used in predicting the student's academic performance in the Mechanical Engineering correlation 1 course. In terms of the relative importance percentage, the ten subjects prior to the correlation 1 course are considered of high importance for the student to pass the subject correlation. It is therefore recommended that all subject advisers for the basic mathematics and sciences should give emphasis on the important topics that are included in the table of specification for the Mechanical Engineering board examination. The study is limited only to Correlation 1, thus the researchers recommend exploring further on all the correlation courses and study the possibility of generating a model that could predict the likelihood of passing the Mechanical Engineering board examination.

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