A Study on Correlation of Subjects on Electrical Engineering Course Using Artificial Neural Network (ANN)

Fathiah Zakaria[1], Siti Aishah Che Kar[2*], Rina Abdullah[3], Syila Izawana Ismail[4], & Nur Idawati Md Enzai[5]

[1]School of Electrical Engineering,
College of Engineering,
Universiti Teknologi MARA,
40450 Shah Alam, Selangor, Malaysia
fathiahz@uitm.edu.my

[2,3,4,5] School of Electrical Engineering,
College of Engineering,
Universiti Teknologi MARA Cawangan Terengganu,
23000, Dungun, Terengganu, Malaysia
[*]sitia2500@ uitm.edu.my,
rinaa5158@ uitm.edu.my,
syila5416@ uitm.edu.my,
nurid333@uitm.edu.my
[*]Corresponding Author

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Abstract: This paper presents a study of correlation between subjects of Diploma in Electrical Engineering (Electronics/Power) at Universiti Teknologi MARA(UiTM) Cawangan Terengganu using Artificial Neural Network (ANN). The analysis was done to see the effect of mathematical subjects (Pre-calculus and Calculus 1) and core subject (Electric Circuit 1) on Electronics 1. Electronics 1 is found to be a core subject with the history of high failure rate percentage (more than 25%) in previous semesters. This research has been conducted on current final semester students (Semester 5). Seven (7) models of ANN are developed to observe the correlation between the subjects. In order to develop an ANN model, ANN design and parameters need to be chosen to find the best model. In this study, historical data from students' database were used for training and testing purpose. Total number of datasets used are 58 sets. 70% of the datasets are used for training process and 30% of the datasets are used for testing process. The Regression Coefficient, *(R)* values from the developed models was observed and analyzed to see the effect of the subject on the performance of students. It can be proven that Electric Circuit 1 has significant correlation with the Electronics 1 subject respected to the highest *R* value obtained (0.8100). The result obtained proves that student's understanding on Electric Circuit 1 subject (taken during semester 2) has direct impact on the performance of students on Electronics 1 subject (taken during semester 3). Hence, early preventive measures could be taken by the respective parties.

Keywords: Artificial neural network, Diploma in Electrical Engineering, Graduate on time, Correlation.

1. Introduction

Various research have been made to study on ways to improve University's teaching and learning methods. Rogers (2019) discusses on ways to evaluate university's teaching and learning in order to improve human capital of university's stakeholders. Based on previous research, continuous research on education such as performance evaluation has becomes vital and essential. Graduate on time (GOT) is one of the objectives and goals set by the Faculty and University when dealings with undergraduate students. A program structure/study plan has been provided by the faculty as the guideline for the students to structure their studies for each semesters, in order to GOT. For Diploma in Electrical Engineering subjects, there are few subjects with pre-requisite or requirement that need to be fulfilled before the students are eligible to register for that particular subject. Failing a subject that has pre-requisite will expose students with the chances of not graduating on time. One of the subjects that is found to have high failure rate percentage among the students in previous semesters are Electronics 1 (ELE232). Hence this research has been done to study the effect of grade obtained by the students in certain subjects on grade of ELE232. In this study, ANN has been used as the medium to predict and estimate the correlation between the mentioned subjects.

Many research have integrate the current technology method such as computational method or Artificial Intelligence(AI) with the educational based studies. Mohamed et al., (2021) have made a study on developing an online problem based learning module which integrate the technology and delivery strategies by using Fuzzy Delphi Technique. Research by Ajol et al., (2020) which apply computational method-Fuzzy logic to enhance student performance evaluation also shown the application of computational method on education related studies are giving significant results.

Recently ANN having rapid development. ANN is a branch of AI which is a field in computer science to develop an intelligent system that act and mimic human brain. AI systems can be used to predict the future performance of a student by looking at their performance over time (Zaharim et al., 2009; Arsad et al., 2011; Kabra & Bithkar, 2011). ANN is one of AI computational methods that is suitable for this purpose (Omar, 2010; Arsad et al., 2014; Arsad et al., 2012). The idea of ANN construction is based on human biological nervous system that contains a lot of neurons and it works like human brain for the purpose of processing information. ANN has become known as a powerful computational tool suitable for pattern recognition, classification, prediction, forecasting and etc. in various application (Oladokun et al., 2008). Among the prominent ANN characteristic are robustness, fault tolerance, high speed information processing, pattern association, mapping capabilities and great competence.

Designing a good ANN system involved the steps of finding the best architecture and parameters of the system. Designing an ANN system is an open concept which there is no specific and systematic guideline available in designing process (Rajasekaran & Pai, 2003). Data is one of the important elements that directly influences the quality of the developed ANN model. Data for training and testing process of ANN are obtained from students' database. The data undergo the pre-processed step to filter out unrelated data and information which may affect the ANN system development. In this research, ANN models are constructed by using a well-know, flexible and efficient software for ANN programming that is MATLAB. Generally, there are two types of ANN learning methods, that are supervised and unsupervised methods. The supervised multilayer feed forward back-propagation has been chosen to be used in this study. The supervised learning method is found to be able to learn directly from the training data fed and update knowledge when necessary (Yao, 1999). In multilayer feed forward back-propagation networks, error is transmitted back to previous layer's nodes while data moves only in one direction (Chen et al., 2008). Transfer function is also used in ANN system design in order to calculate output value of an ANN. The transfer function is categorized into three types: linear, threshold and sigmoid. The syntax that represents the ANN structure in this study is given as:

Net = newff (P, T, S, TF, BTF, PF)

where:

P = Input
T = Output
S = Number of Neurons in Hidden Layer
TF = Transfer Function
BTF = Learning Technique
PF = Performance Function

In this study, the ANN development process involved the construction of several multilayer feed-forward back-propagation networks. Each of the networks consist of input layer, hidden layer and output layer. The multilayer feed-forward back-propagation networks are found to be the most widely used ANN model (Shanmugam & Daniel, 2011). ANN has the capability to learn from data fed and improve its performance through training process. Generally, training stage of an ANN involves few steps: training data, creation of network object, network training and simulation of the network response to the new inputs. Once the ANN is fully trained, the training process will be halted. Since designing ANN is an open concept, the parameters and setting of the ANN model are varied using trial and error method. In this study, the grade of particular subject obtained by the students and grade obtained for ELE232 were used as input and output respectively.

Training process is then followed by the testing process. During the testing stage, another data set is used to evaluate the performance of the trained ANN network. During testing stage, values of correlation coefficient, R were recorded in order to evaluate the performance of developed model. R is computed to analyze correlation between network outputs and targeted output by measuring the linear relationship (Annapoorani & Umamaheswari, 2012). The R graph plot the best linear fit between targeted output and real output from the ANN model. Hence, a good ANN model that has values of R close to 1 shows a strong correlation between targeted output (from data) and real output (from testing process).

2. Methodology

Paper Seven (7) ANN models are developed (Model 1-7) and the input and the targeted output of the developed ANN models are tabulated in Table 1. Figure 1 illustrate the developed ANN block diagram. The ANN will produce the output based on input and targeted output feed to the ANN. In this study, the inputs consist of Grade of subjects including Pre-Calculus (MAT133), Calculus 1 (MAT183) and Electric Circuit 1 (EEE121). The targeted output of the ANN is the grade of Electronics 1 (ELE232). The overall flowchart of developing an ANN model is shown as in Figure 2. To develop an ANN model, parameters such as momentum constant (MC), learning rate (LR), transfer function, number of hidden layer and neurons need to be determined.

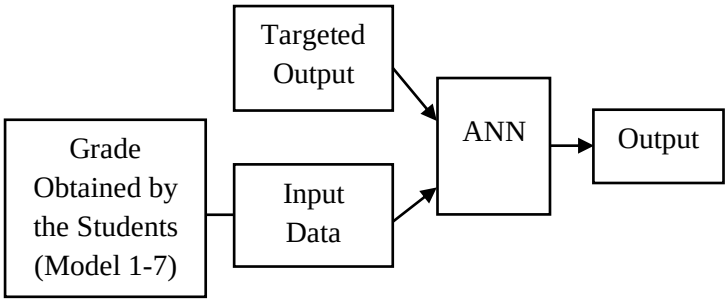

Fig.1 Developed ANN Block Diagram

In this study, these parameters are varied and determined heuristically (using trial and error method). The model structure that has been selected is three-layer structure which consists of input, hidden layer and output layers. The ANN model structure is illustrated as in Figure 3. The learning technique used in this study is Lavenberg-Marquart (LM) since it is found as a simple, robust and fast algorithm (Harlow, 2004).

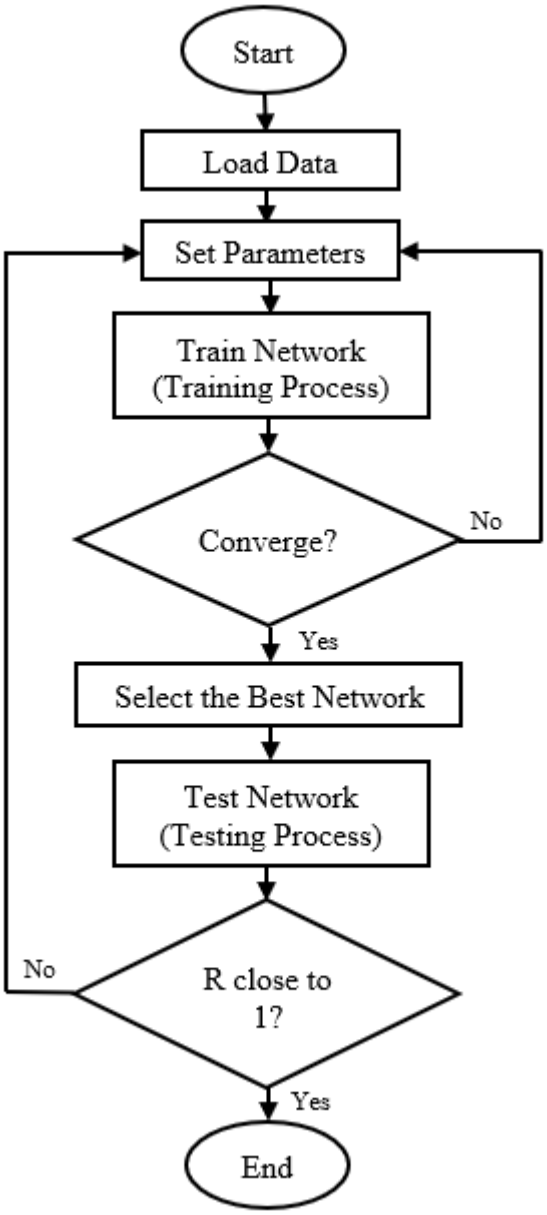

Fig. 2 ANN Flowchart

In order to improve the ANN model performance, a technique called early stopping is applied. This technique is able to avoid overfitting and generalization and the network bias and weight are created randomly.

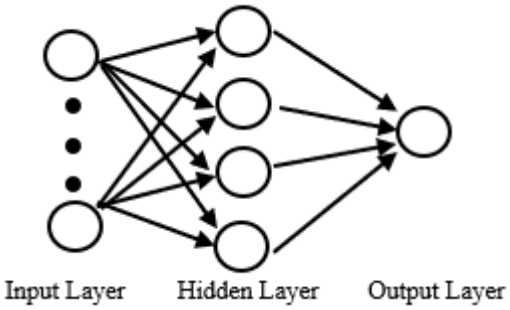

Fig. 3 ANN Model Structure

The process of developing ANN models begins with the selection of parameters. The first stage is variation of neuron's number and transfer function in hidden layer while the other parameters are kept fixed. The simulation works can be divided into two parts: Part 1 and Part 2. For Part 1, the transfer function used is 'tansig' and the number of neurons in hidden layer is decremented in the range of 20 to 2. The step is done to provide systematic variation of the hidden layer value since designing ANN does not have any systematic guideline and heuristic in nature. The transfer function is a mathematical formula that determines the output of processing neurons (Tsai et al.,2006; Abhishek et al., 2012; Wu & Ren, 2011; Abhishek et al., 2012; Adam et al., 2012).

Table 1. List of Input Parameters and Output Parameters

Model	Input Parameters (Grade)	Output Parameters (Grade)
1	Pre-Calculus (MAT133)	Electronics 1 (ELE232)
2	Calculus 1 (MAT183)	
3	Electric Circuit 1(EEE121)	
4	Electric Circuit 1(EEE121) Pre-Calculus (MAT133)	
5	Electric Circuit 1(EEE121) Calculus 1 (MAT183)	
6	Electric Circuit 1(EEE121) Pre-Calculus (MAT133) Calculus 1 (MAT183)	
7	Pre-Calculus (MAT133) Calculus 1 (MAT183)	

The transfer function in the output layers is kept fixed in order to see the effect of transfer function variation in the hidden layer. In this research, the transfer functions used in output layers is 'purelin'. In Part 2, the number of neurons in hidden layer used is 'logsig' and also varies as in part 1. Both simulation works of Part 1 and Part 2 are done in order to see the effect of varying the number of neurons in hidden layer by using different transfer function: 'tansig' and 'logsig'.

The next step is variation of the LR and MC values. Both values of LR and MC are varied from 0.02 to 1.00, incremented in steps of 0.02. These steps were conducted to see the effect of LR and MC variation towards the performance of the ANN models. This increment is considered acceptable interval for a maximum range of 1.00. The increment step has been selected as 0.02 to provide a systematic way in designing an ANN model. There are 50 LR values and 50 MC values used throughout the simulations works. These designing steps are applied to Model 1. Once the architecture and parameters have been decided for Model 1, the other models (Model 2-7) will use the same network architecture and parameters setting.

3.0 Results

Seven (7) ANN models were developed by using different set of inputs. 70% of the total data (41 sets) were used for training process and 30% (17 sets) were used for testing process. The correlation coefficient, *R* during testing process of the ANN models were observed. It is a best linear fit between

targeted output(data) and real output from the ANN model. The *R* value from testing process shows how well the ANN models are learning from the training data. Table 2 shows the values of *R* obtained for each of the respective model. Figure 4 until Figure 10 illustrate the graphs plot of the outputs versus targeted outputs of each models.

Model 3 has the highest *R* values which is 0.8100. Model 3 has been feed with Electric Circuit 1 (EEE121) as the input and Electronics 1 (ELE232) as the output. Comparison on the results was made. The Model with EEE121 subject (Model 3,4,5 and 6) obtained higher *R* values as compared to the Models without EEE121 subject (Model 1,2 and 7). It can be seen that EEE121 subject which is taken during Semester 2 has significant impact on the grade obtained by the students for ELE232 during Semester 3. Based on the syllabus of the subjects, it can be concluded that the basic circuit analysis concept in EEE121 subject is crucial and vital for ELE232 subject.

Model 1 and 2 have lower *R* values as compared to Model 3. Model 3 has 24% and 23% higher *R* values compared to Model 1 and Model 2 respectively. Both Model 1 and Model 2 are developed by using mathematical grades and ELE232 as the input and output respectively. These results show less correlation between mathematical subjects and ELE232. The mathematical subjects' grades have less significance impact on the grades of ELE232 as compared to EEE121 subject.

Table 2. Values of *R* for Respective Models

Model	R Values
1	0.6185
2	0.6239
3	0.8100
4	0.8005
5	0.8016
6	0.7316
7	0.7122

Based on the *R* value obtained, the selected ANN models and respective ANN parameters with the highest *R* value (Model 3) is summarized in Table 3.

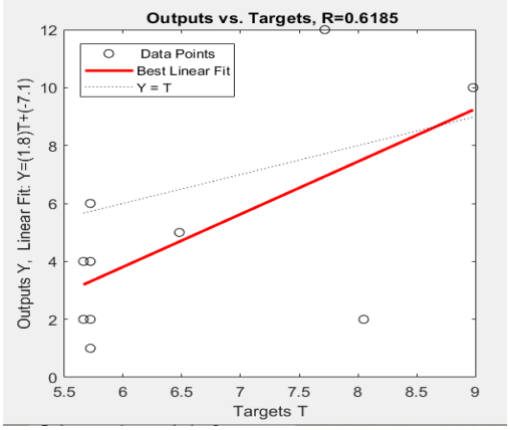

Fig. 4 Correlation Coefficient, *R* of ANN for Model 1

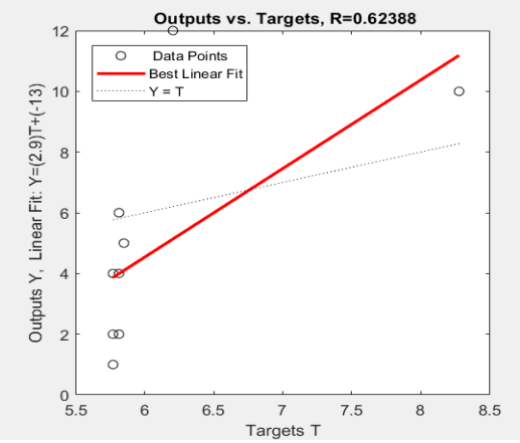

Fig. 5 Correlation Coefficient, *R* of ANN for Model 2

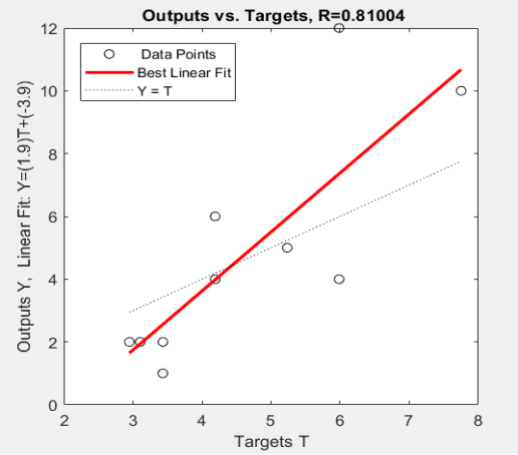

Fig. 6 Correlation Coefficient, *R* of ANN for Model 3

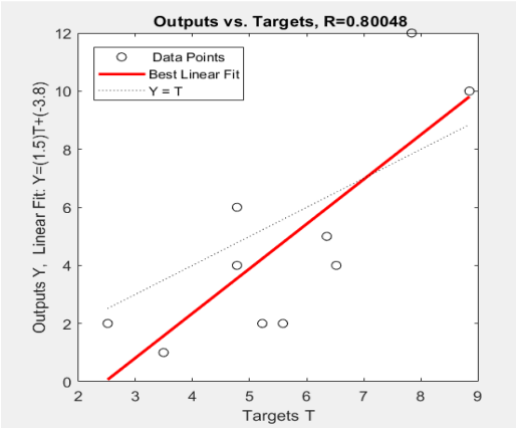

Fig. 7 Correlation Coefficient, *R* of ANN for Model 4

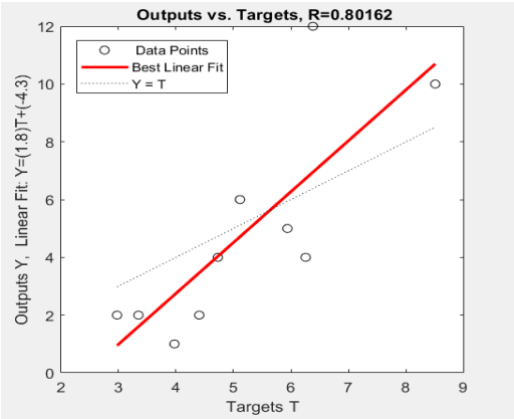

Fig. 8 Correlation Coefficient, *R* of ANN for Model 5

As the result, the selected ANN configuration for Model 3 is a three-layer feed forward back-propagation network with 4 neurons in hidden layer. The learning rate and momentum constant values are 0.5 and 0.95 respectively and the training algorithm used is Levenberg-Marquardt.

Fig. 9 Correlation Coefficient, *R* of ANN for Model 6

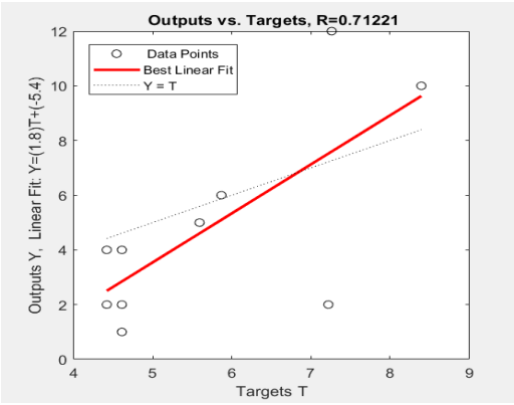

Fig. 10 Correlation Coefficient, *R* of ANN for Model 7

Table 3. Properties of Developed ANN for Model 3

ANN Properties	Model 3
ANN Configuration	[1 4 1]
Transfer Function	tansig
Learning Rate	0.5
Momentum Constant	0.95
Regression Coefficient, R	0.8100
Training Algorithm	Lavenberg-Marquart

4. Discussion

Based on the results obtained, comparison on effect of grade obtained in mathematical subjects (MAT 133 & MAT 183) and Electrical Circuit (EEE121) in previous semester to the Electronics 1 (ELE232) which is found to be a high failure rate subjects in Diploma of Electrical/ Electronics Engineering has been made. The simulation results show less correlation between mathematical subjects and ELE232, which has been proven by the low value of *R*. The correlation between EEE121 and ELE232 is having higher *R* value. It shows that, the ability of students to understand the basic electrical circuit analysis concept in EEE121 (taken in semester 2) playing major impact on the ability of students to perform in ELE232 (taken in semester 3). Failure of students to grab the basic concept will result to failure in the ELE232 subject which will leads to higher failure rate percentage (more than 25%). Failing ELE232 appears to be particularly demoralizing and is most likely the main reason for the early student dropout from the University. Furthermore, the high failure rate will affect the Faculty's performance and University's objectives.

The application of ANN to study the correlation between the subjects and engineering course give significant impact on reducing the time taken to do the correlation analysis. With the help of AI, the time taken to complete the analysis is reduced and the analysis is become easier. As compare to previous research by Bischof et.al, (2015), the research of comparing results in mathematics with the core engineering subjects took more than ten years to complete. With a reliable dataset, AI will most likely results in prominent findings to the study. This study focused on developing ANN models by exploring data collected from university's system in order to understand and improve educational process. Many researchers have done studies on education area using AI obtained positive results such as Naser et. al., (2015) and many more. This study meet the objective of the research in order to find which subject give significant impact to ELE232 using an easier method and less computational time taken. As mentioned before, ELE232 is a subject that has high failure rate almost every semester. It can be concluded that EEE121 is the subject that need to be given exceptional attention and concern for Diploma in Electrical/Electrical Engineering at Universiti Teknologi MARA(UiTM) Cawangan Terengganu in order to avoid student early dropout, maintaining students' CGPA, GOT and meet the Faculty's and University's objectives.

5. Conclusion

In order to achieve University's objective to improve the percentage of GOT among the students and to reduce the percentage of failure rate that is higher than 25%, proactive actions measures should be taken. Early preventive measures taken in semester 2 might improve the overall performance of Faculty and University since the EEE121 subject is taken by the students during semester 2. From this research finding, proactive actions should be taken by the University and Faculty such as creating a better lesson plan during Semester 2, choosing experienced lecturers to teach the particular subject, deliver the lesson using different medium of teaching such as blended learning and taking proactive preventive measures before final exam such as clinic day.

For future works, analysis of the ANN performance should consider another evaluation method such as Mean Square Error(MSE) and Mean Absolute Error (MAE) to verify the efficiency of the system. The process of designing ANN model (the parameter selection process) could be optimized by

using another computational method such as Evolutionary Programming, Particle Swarm Optimization and etc. This optimization could process provides more efficient platform for analysis since ANN is heuristic in nature. This area of research is essential since it uses computational method analysis which is more systematic in order to find the root cause of problems related to academic performance. Once the problem is identified, future plans and measures could be planned.

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