



Implementation of Simple Linear Regression for Predicting of Students' Academic Performance in Mathematics

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Abstract

Predicting student academic performance is an interesting thing to research. Student academic performance can be used to determine the level of student mastery of the subject matter that has been delivered. This research uses academic and personal data of secondary students on mathematics subject scores in Portugal with 395 data records. The purpose of this research is to study how linear regression is applied in order to determine the predictive results of students' academic performance. Prediction evaluation is done by calculating attribute correlation with class, Root Mean Squared Error (RMSE), and Mean Absolute Percentage Error (MAPE). The results of this research test the accuracy obtained linearly with correlation results, namely class failure (d) has the smallest RMSE and MAPE with an RMSE value of 1.148 and a MAPE of 9.82% of students' academic performance in mathematics. The results of the data analysis show that the failure variable has a positive effect on G3, where the probability value of the F test, the significance value for the simultaneous failure effect on G3 is $0.006 < 0.05$ and from the analysis of the coefficient of determination it is known that the failures variable is significant to the dependent variable with a large influence 63,8 % (model 2).

Keywords: Linear Regression; MAPE; Mathematics; Student Academic Performance

Abstrak

Memprediksi prestasi akademik mahasiswa merupakan hal yang menarik untuk diteliti. Prestasi akademik siswa dapat digunakan untuk mengetahui tingkat penguasaan siswa terhadap materi pelajaran yang telah disampaikan. Penelitian ini menggunakan data akademik dan data pribadi siswa sekolah menengah pada nilai mata pelajaran matematika di Portugal dengan 395 data record. Tujuan dari penelitian ini adalah untuk mempelajari bagaimana regresi linier diterapkan untuk menentukan hasil prediksi prestasi akademik siswa. Evaluasi prediksi dilakukan dengan menghitung korelasi atribut dengan kelas, Root Mean Squared Error (RMSE), dan Mean Absolute Percentage Error (MAPE). Hasil penelitian ini menguji akurasi yang diperoleh secara linier dengan hasil korelasi yaitu kelas gagal (d) memiliki

RMSE dan MAPE terkecil dengan nilai RMSE sebesar 1,148 dan MAPE sebesar 9,82% terhadap prestasi akademik siswa dalam matematika. Hasil analisis data menunjukkan bahwa variabel kegagalan berpengaruh positif terhadap G3, dimana nilai probabilitas dari uji F nilai signifikansi pengaruh kegagalan simultan terhadap G3 adalah $0,006 < 0,05$ dan dari analisis koefisien determinasi diketahui bahwa variabel failuers signifikan terhadap variabel dependen dengan besar pengaruh 63,8 % (model 2).

Kata Kunci: Matematika; MAPE; Prestasi Akademik Siswa; Regresi Linear

Introduction

Learning is a process to gain knowledge, improve skills, behavior, and attitudes, and strengthen personality (Martsiswati & Suryono, 2014). In this regard, student learning activities play an important role in determining student academic performance. One of the subjects that must be studied by students is mathematics. Mathematics learning activities are expected to be contextual in nature by linking mathematical concepts with activities and student life environment in order to develop student academic performance (Auliya, 2019; Malasari, Herman, & Jupri, 2019; Bhoke, 2020; Richardo, 2020; Taskiyah & Widyastuti, 2021). Student academic performance is defined as a measure of knowledge gained from formal education and is shown through test scores (Lawrence & Vimala, 2012). In line with that opinion, Goods defines student academic performance as the acquired knowledge and skills developed in various subjects at school which are usually determined by test scores or by grades given by teachers (Annes & Redlin, 2013). Learning achievement reflects mastery of the subjects determined by the grades or numbers given by the teacher. Student academic performance is important to study for several purposes such as to determine the level of student mastery of a subject matter that has been delivered by a teacher (Izzaty, Ayriza, & Setiawati, 2017). One of them is that students' academic performance can be used to determine the level of student mastery of the subject matter that has been delivered. In this study, students' academic performance will be predicted using the linear regression method. This is what underlies the researcher to take this study because this study both uses students' academic performance to see student performance. The method to see the performance in this study using the linear regression method.

Linear regression is a statistical tool used to determine the effect of one or several variables on one variable (Katemba & Djoh, 2017). Regression measures how much a variable can affects other variables such that the value of a variable based on other variables can be predicted. Prediction is a conjecture or prediction about the occurrence of an event or events in the future which can be qualitative

(not in the form of numbers) or quantitative (in the form of numbers) (Novianty, dias Palasara, & Qomaruddin, n.d., 2021).

Here are some studies that use the linear regression method for the prediction process, linear regression can produce predictions of patient visits at the hospital with several criteria, where there are 26 linear regression prediction models that have an error value of less than 20% meaning that it has an accuracy of 80% or includes in the very good and good categories (Baihaqi, Dianingrum, & Ramadhan, 2019). The simple linear regression method is suitable for forecasting Mutual Fund income in a year (Jayanti, 2020). Linear regression algorithm can predict profits and losses at PT. SriUlina Ersda Karina (Simbolon, 2021). Simple linear regression method can determine accurate prediction results to predict drug stock with an accuracy of 98.505% (Muttaqin & Srihartini, 2022). The linear regression method is used for forecasting the acceptance of prospective students (Bhakti, Kusdinar, & Sunarto, 2020), (Almumtazah, Azizah, Putri, & Novitasari, 2021). Research using the same method was also carried out by (Bengnga & Ishak, 2018) to discuss the prediction of the number of semester students with the results of an accuracy rate of more than 90% so that it can predict the number of students correctly. Furthermore research was carried out by (Mulyani et al., 2020) with the multiple linear regression method discussing estimation the selling price of a used car which has an estimated price of 2.65%. Research using a simple linear regression method was also carried out to predict the number of foreign tourist visits during the Covid-19 pandemic (Rahmawati, Kristanto, Pratama, & Abiansa, 2022) and to predict sales of the best-selling shoe product (Pohan, Halmidar, & Irmayanti, 2022).

Here is to show some the previous research regarding predictions using the linear regression approach. (Farizal, Rachman, & Rasyid, 2014) in their research to predict fuel with the results of this method is able to produce an accuracy of 94,82%. In this study, forecasting was done using the multi linear regression (MLR) method, while in our study we used linear regression. This study was taken because both are used to predict variables. Similar research was also conducted by (Nafi'iyah, 2015) with results showing the use of the linear regression method provides an accuracy of 80%. The research applied the Clustering method with the Clustering Neural Network algorithm in the case of grouping student expertise based on course grade transcripts as a recommendation to take the field of expertise according to the student's abilities. This study was chosen because it grouped student skills together. The results of the study (Imtiyaz, 2017) also show the same thing where the use of method linear regression to prediction produce accuracy of 91,6 %. This study discusses a decision support system for chili cultivation based on rainfall predictions using a simple linear regression method. Regression method is used to

predict rainfall by modeling rainfall data in previous years. Researchers took this study because they both use a simple linear regression method to predict the variable.

The application of the multiple linear regression method shows that the results of the accuracy test resulted in an average RMSE of 8.68 and an average MAPE of 10.15% (Masruroh, 2020). Thus, in this study the back propagation neural network method has better accuracy in predicting the value of the National Examination for Junior High School students. While in this study only the regression method was used. In other words, this system of national examination is able to provide an accuracy of 89.85%. In addition, (Masruroh & Mauladi, 2020) in his research also showed that the use of the linear regression method for predicting national exam scores was able to produce an RMSE of 0.5. In this study, the linear regression method will be implemented in a web-based national exam result prediction system. The data used in the trial application of the linear regression method. This is what underlies the researcher taking the title because the application of the linear regression method can be used to predict. Thus, it can be concluded that the use of the linear regression method can provide a relatively small error in the prediction results. The reason that underlies researchers taking public data is because public data is freely available to be accessed and utilized by the public. In addition, public data is definitely valid because it comes from a clearly stated source. The data is expected to be able to represent the population of the research variables.

The difference between this research and the previous researches are that the data used in this study is public data, other than that another difference is that this research is in the form of implementing a linear regression method using Python. The use of Python in this study is to visualize the results of research that has been carried out using the linear regression method. This visualization is useful for knowing the accuracy value of each data split. Therefore, the purpose of this research is to study how linear regression is applied in order to determine the predictive results of student academic performance.

Method

This study implements the linear regression algorithm for predicting students academic performance in mathematics. The stages of the research method consisted of 4 stages consisting of data set, pre processing, method implementation and evaluation. In this study there are 4 stages, because this research uses public data (McFee et al., 2018). The stages of the research are shown in Figure 1.

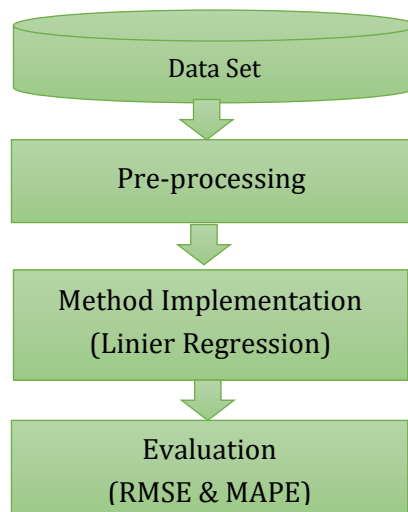


Figure 1. The Stages of Research

An explanation of the four research steps as shown in Figure 1 is as follows.

Data Set

The data is provided by UCI (*University of California, Irvine*) *Machine Learning Repository*, that can be accessed in website <https://archive.ics.uci.edu>. This data approximate student achievement in Portuguese secondary school education. Two datasets are provided regarding performance in the different subjects : Mathematics (mat) and Portuguese (por). The subjects used in this study are Mathematics. The number of data records is 395.

Table 1. Dataset Attribute

	Attributes	Interval
Failures	number of past class failures	n if $1 \leq n < 3$, else 4
Study Time	weekly study time	1 - <2 hours, 2 - 2 to 5 hours, 3 - 5 to 10 hours, or 4 - >10 hours
Free Time	free time after school	from 1 - very low to 5 - very high
Absences	number of school absences	0 - 93
G3	final grade course Math	0 - 20

Method Implementation

The prediction method used in this research is linier regression. The following are the steps for applying the linier regression technique (Damayanti, 2021):

1. Determine the independent variable (x) and dependent variable (y).
2. Grouping the data so that the existing data doesn't experience interference during data processing caused by problems with the data.
3. Determining constants (a) and coefficient (b) can be done by the following formulas:

$$a = \frac{(\sum y)(\sum x^2) - (\sum x)(\sum xy)}{n(\sum x^2) - (\sum x)^2} \quad (1)$$

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad (2)$$

4. a is a constant, b is a coefficient or intercept, x is the independent variable, and y is the dependent variable.
5. Making predictions by the linear regression below:

$$Y = a + Bx$$

A is a constant and b is a coefficient or intercept .

Correlation is one of several statistical analysis methods that are useful for determining the relationship between two quantitative variables (Herlina, 2019). Based on this definition, the correlation statistic is a useful method or method to find out whether or not there is a linear relationship between variables. The following is the correlation formula (Bertan, Dundu, & Mandagi, 2016):

$$r = \frac{n \sum xy - (\sum x)(\sum y)}{\sqrt{[n \sum x^2 - (\sum x)^2][n \sum y^2 - (\sum y)^2]}} \quad (3)$$

Data analysis used linear regression and was carried out with the help of the SPSS application program. Based on the regression model, several t-tests and F-tests can be carried out, this t-test is to determine whether or there isn't a partial (own) effect given by the independent variables individually on the dependent variable (Y). While the F test aims to determine whether or there isn't a simultaneous (together) effect given by the independent variable on the dependent variable (Y) (Aprilyanti, 2017).

Evaluation

At the prediction analysis stage, the accuracy test calculation is carried out by comparing the results issued by the system with the actual value such that the accuracy can be calculated by using Root Mean Squared Error (RMSE) and Mean Absolute Percentage Error (MAPE). RMSE and MAPE can be calculated by the following formula (Masruroh, 2020):

$$RMSE = \sqrt{\frac{\sum |D_t - F_t|^2}{n}} \quad (4)$$

$$MAPE = \frac{\sum |D_t - F_t| / D_t}{n} \quad (5)$$

where:

D_t = actual data

V_t = predictive value

N = amount data

Furthermore, at this stage implementation is also carried out by using Python. This is based on research that the random forest model in this study is a machine learning made in the form of a website using flask in python so that it can be used independently in determining the prediction of apartment rental prices in DKI Jakarta (Mulyahati, 2020).

Results

Method Implementation

The prediction process using the linier regression method in this study is the calculation of the correlation between attributes and existing classes. The data used in manual calcuations using excel with a total sample of 10 records are as follows :

Table 2. Data Used in Manual Calcuations Using Excel

Student Number	Study Time	Failuers	Free Time	Absences	G3 (y)
1	1	3	5	2	7
2	2	1	3	14	11
3	2	0	2	4	11
4	2	0	3	6	13
5	1	3	5	0	10
6	2	2	4	0	11
7	2	0	2	0	14
8	4	0	5	6	13
9	2	0	2	2	13
10	2	0	4	14	11

Based on the data in Table 2, the next step is to calculate R Square test.

Table 3. R Square Test Result

Model	R	R Square
1 (study time)	,609	,371
2 (failures)	,799	,638
3 (free time)	,566	,320
4 (absences)	,008	,00001

From these calculations, it can be seen how much influence each attribute has on the final period value. The results obtained are model 2 (failures) the magnitude of the influence of the independent variable (failures) on the dependent variable 63.8% followed model 1 (study time) have value 37.1% next model 3 (free time) 32.0% last model 4 (absences) 0.01%.

Table 4. Regression *t* Test Result

Model	Coefficients		
	B	T	Sig
1 (constant)	8,400	5,670	,000
study time	1,500	2,172	,062
2 (constant)	12,523	24,833	,000
Failures	-1,248	-3,754	,006
3 (constant)	14,538	8,504	,000
free time	-,897	-1,941	,088
4 (constant)	11,385	12,263	,000
Absences	,003	,023	,982

From the results of *t* accordance with Table 4 the value of sig. the effect of study time on G3 is $0,062 > 0,05$, failures for G3 is $0,006 < 0,05$, free time for G3 is $0,088 > 0,05$ and absences for G3 is $0,982 > 0,05$. It can be concluded that the failures factor has an effect G3.

After obtaining the constants, coefficients, and correlations between the attributes and the student's final period value, then predictions are made using linier regression using the formula $Y = a + Bx$. Prediction results can be seen in Table 5:

Table 5. Prediction Result

	actual G3	$Y_{model 1}$	$Y_{model 2}$	$Y_{model 3}$	$Y_{model 4}$
1	7	9,9	8,785	10,057	11,391212
2	11	11,4	11,277	11,849	11,428484
3	11	11,4	12,523	12,745	11,397424
4	13	11,4	12,523	11,849	11,403636
5	10	9,9	8,785	10,057	11,385
6	11	11,4	10,031	10,953	11,385
7	14	11,4	12,523	12,745	11,385
8	13	14,4	12,523	10,057	11,403636
9	13	11,4	12,523	12,745	11,391212
10	11	11,4	12,523	10,953	11,428484

Table 6. Linier Regression F Test Result

ANOVA ^a				
Model		Sum of Squares	F	Sig
1	Regression	13,500	4,716	,062
	Residual	22,900		
	Total	36,400		
2	Regression	23,219	14,092	,006
	Residual	13,181		
	Total	36,400		
3	Regression	11,655	3,768	,088
	Residual	24,745		
	Total	36,400		
4	Regression	,002	,001	,982
	Residual	36,398		
	Total	36,400		

Based on the F test in table 6 which was carried out, it was obtained that the failuers (model 2) had a simultaneous positive effect on G3 (Y).This is based on the value of sig $0,006 < 0,05$.

Evaluation

Testing accuracy by comparing the results issued by the system with the actual value so that the accuracy can be calculated using *Root Mean Squared Error* (RMSE) and *Mean Absolute Percentage Error* (MAPE). This is according to research (Masrurroh & Mauladi, 2020) which uses RMSE and MAPE to determine the prediction system in determining the junior high school national exam scores. Based on the prediction results in Table 4, the results of the RMSE and MAPE calculations are obtained as presented in Table 5:

Table 5. RMSE and MAPE Calculation Results

Atribut	RMSE	MAPE
Model 1	1,5133	11,1%
Model 2	1,148	9,82%
Model 3	1,573	11,1%
Model 4	1,908	14,7%

The results of the accuracy test in table 5 obtained are linear with the correlation results that have been calculated in table 3, namely failures (d) have the smallest RMSE and MAPE with an RMSE value of 1,148 and MAPE of 9.82% followed by study time (c) then free time (e) and absences (f). This research in line with research (Katemba & Djoh, 2017) testing using MSE and MAPE obtained the value of MSE 43,112% and MAPE 20,001% then testing using MAPE is much better in calculating the prediction accuracy of coffee production. For visualization of the comparison graph of the prediction results, it can be seen in Figure 2, that the comparison graph of the actual G3 with the predicted G3 based on failures has a line that is closest to the actual G3.

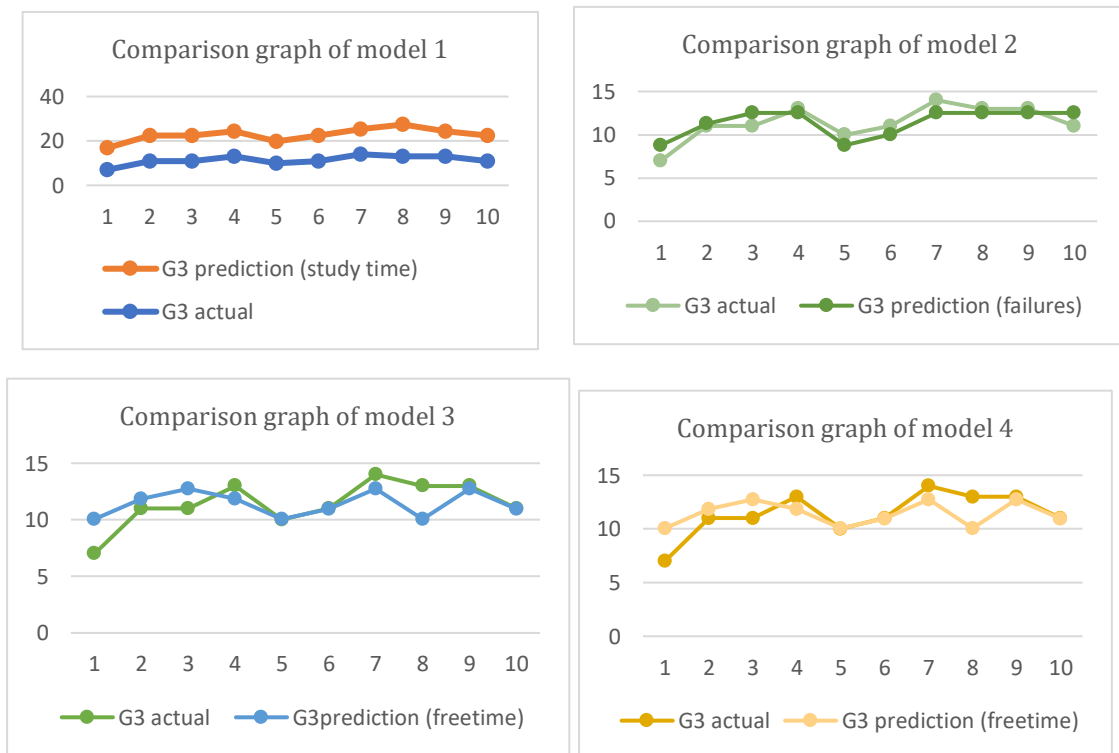


Figure 2. Comparison Graph of Actual G3 with Predicted G3

Furthermore, at this stage implementation is also carried out with Python. This is according to research (Aulia, 2021) that the implementation of the programming language that the implementation of the programming language

obtained line equations in 6 different types of oil and execution time where the result is Python takes longer to execute compared to R Studio which is faster by using less code syntax, then the results of the line equation are different because Python uses 20% dataset and R Studio use the entire data to analyze. Figure 3 is a results of the run program.

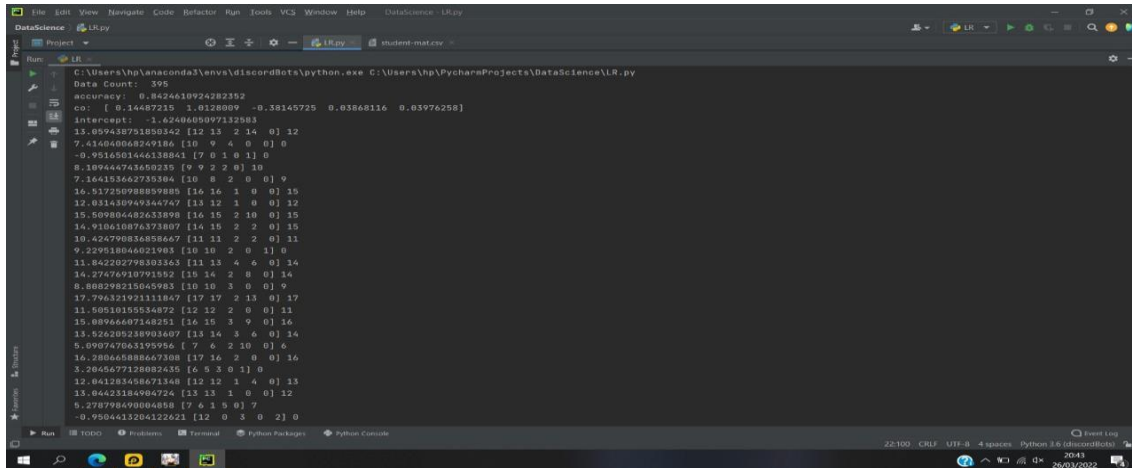


Figure 3. Displayed Results of the Run Program

Discussion

The results of the implementation of predictions with Python obtained 93,28% accuracy results. Accuracy is a method of testing the algorithm for the degree of proximity between the values of actually with predicted value (Ayudhitama & Pujianto, 2020). Based on the results of the implementation, it can be concluded that the use of the linier regression method for predicting student's academic performance in mathematics can provide relatively large accuracy in the prediction results in line with research that has been carried out (Setyoningrum & Rahimma, 2022). The results how much influence each attribute has on the final period value of attributes used in this study have a significant difference in value. It is hoped that in the next research, it can be compared with other attributes.

Conclusion

The conclusion obtained from this study is that the accuracy test results obtained are linear with correlation results, namely class failure (model 2) has the smallest RMSE and MAPE with an RMSE value of 1.148 and a MAPE of 9.82% of students' academic performance in mathematics. Based on the results of the F test and t test, the results show that the failuers variable is significant to the dependent variable with a large influence 63,8 % (model 2). For further research, other prediction methods can be used.

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