**Programming Assignment01**

|  |
| --- |
| **Submission guide**  1. Write answers for following individual questions in this word file  2. Write your code using provided Jupyter notebook file   * Do not import other packages that are not imported in the given file. * After completing your code, run script and submit with the printed results for answering questions in this word file. |

Name : Choi Jiwoo

ID : 19102100

**[1. Linear regression (78pt)]**

Apply a multiple linear regression on the given dataset.

Target analysis: The given dataset aims to predict "G3" of students using several explanatory variables related to individual students.

[Variables]

|  |  |
| --- | --- |
| **Variable name** | **Description** |
| **G3** | **Dependent variable, which means final grade (numeric from 0 to 20)** |
| School | Student’s school (binary: “GP”-Gabriel Pereira or “MS”-Mousinho da Silveira) |
| Sex | Student’s sex (binary: “F”-female or “M”-male) |
| Age | Student’s age (numeric from 15 to 22) |
| Address | Student’s home address type (binary: “U”-urban, “R”-rural) |
| Famsize | Family size (binary: “LE3”-less or equal to 3, “GT3”-greater than 3) |
| Pstatus | Parent’s cohabitation status (binary: “T”-living together, “A”-apart) |
| Medu | Mother’s education (numeric: 0 – none, 1 – primary education (4th grade), 2 – 5th to 9th grade, 3 – secondary education, or 4 – higher education) |
| Fedu | Father’s education (numeric: 0 – none, 1 – primary education (4th grade), 2 – 5th to 9th grade, 3 – secondary education, or 4 – higher education) |
| Mjob | Mother’s job (nominal: “teacher”, “health” care related, civil “services” like administrative or plice, “at\_home”, or “others”) |
| Fjob | Father’s job (nominal: “teacher”, “health” care related, civil “services” like administrative or plice, “at\_home”, or “others”) |
| Reason | Reason to choose this school (nominal: “mother”, “father”, or “other”) |
| Guardian | Student’s guardian (nominal: “mother”, “father” or “others”) |
| Traveltime | Home to school travel time (ordinal: 1 – less than 15 minutes, 2 – 15 to 30 minutes, 3 – 30 minutes to 1 hour, or 4 – more than 1 hour) |
| Studytime | Weekly study time (ordinal: 1 – less than 2 hours, 2 – 2 to 5 hours, 3 – 5 to 10 hours, or 4 – more than 10 hours) |
| Failures | Number of pass class failures (ordinal: as it is for 1 to 3 failures, or 4 – 4 or more failures) |
| Schoolsup | Extra educational support (binary: yes or no) |
| Famsup | Family educational support (binary: yes or no) |
| Paid | Extra paid classes within the course subject (binary: yes or no) |
| Activities | Extra-curricular activities (binary: yes or no) |
| Nursery | Attended nursery school (binary: yes or no) |
| Higher | Wants to take higher education (binary: yes or no) |
| Internet | Internet access at home (binary: yes or no) |
| Romantic | With a romantic relationship (binary: yes or no) |
| Famrel | Quality of family relationship (ordinal: from 1 to 5) |
| Freetime | Free time after school (ordinal: from 1 to 5) |
| Goout | Going out with friends (ordinal: from 1 to 5) |
| Dalc | Workday alcohol consumption (ordinal: from 1 to 5) |
| Walc | Weekend alcohol consumption (ordinal: from 1 to 5) |
| Health | Current health status (ordinal: from 1 to 5) |
| Absences | Number of school absences (numeric: from 0 to 93) |
| Course | Course of the grade (binary: “math” or “Portuguese”) |
| G1 | First period grade (numeric: from 0 to 20) |
| G2 | Second period grade (numeric: from 0 to 20) |

This dataset is a slightly modified version of a publicly disclosed dataset only for the purpose of this assignment.

**Part 1: Preprocessing**

1-(1) This dataset contains many missing values. If the proportion of missing values in a variable exceeds 80%, the variable should be excluded from the dataset. Is there any variable to be excluded? (3pts)

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* Variables ‘famsize’, ‘activities’ should be excluded since they exceeds 80% of missing values.

1-(2) After excluding some variables, if necessary, some rows containing missing values should be deleted from the dataset. How many samples need to be removed? Additionally, after removing samples with missing values, how many samples remain in the dataset? (3pts)

* Since linear regression does not accept missing values, every rows which has missing values after removing two variables of 1-(1) should be removed.
* 283 variables were removed. (1044 – 761)
* 761 samples remained.

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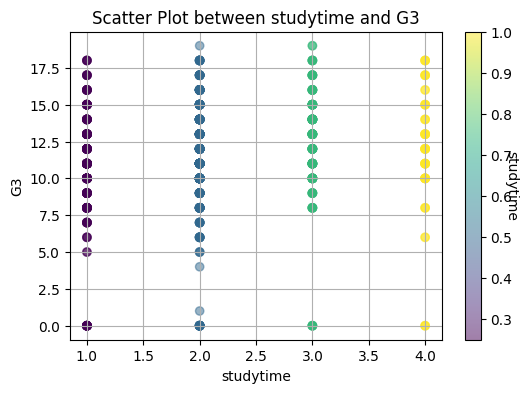
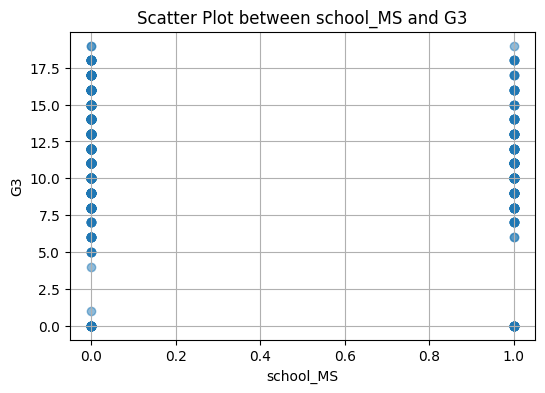
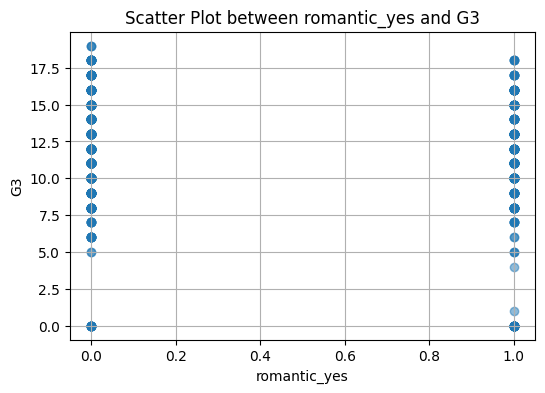
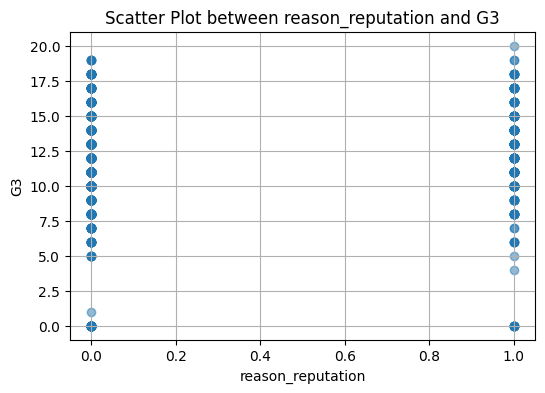
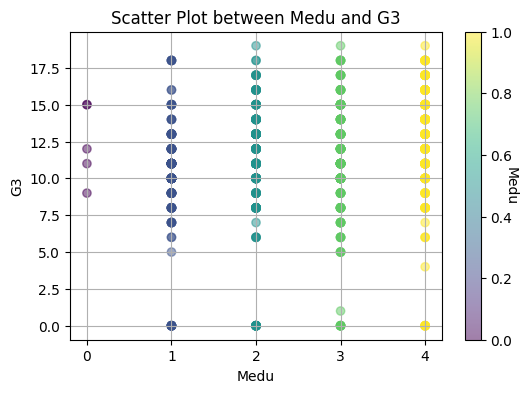
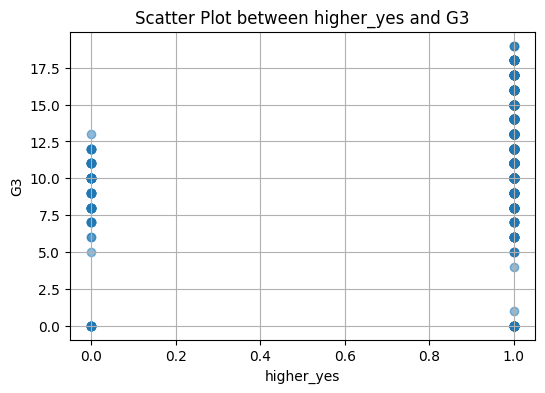
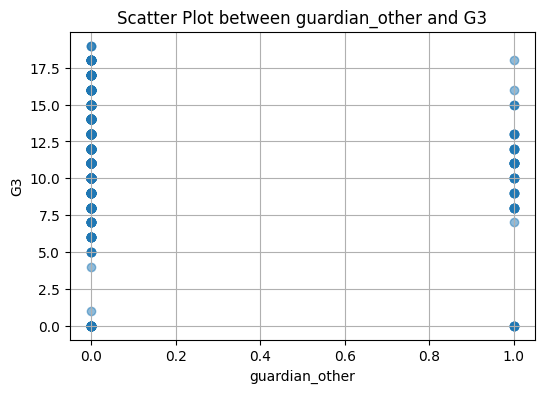
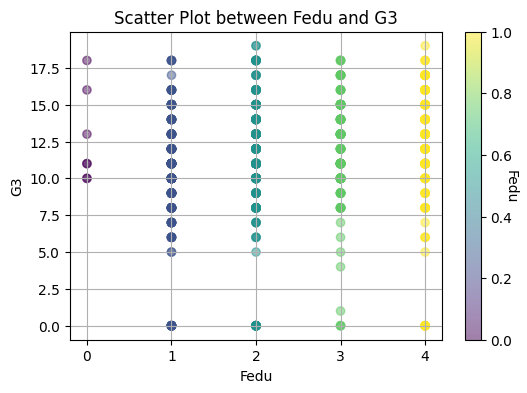
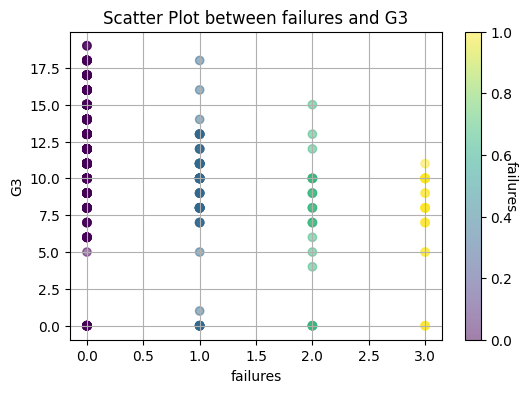
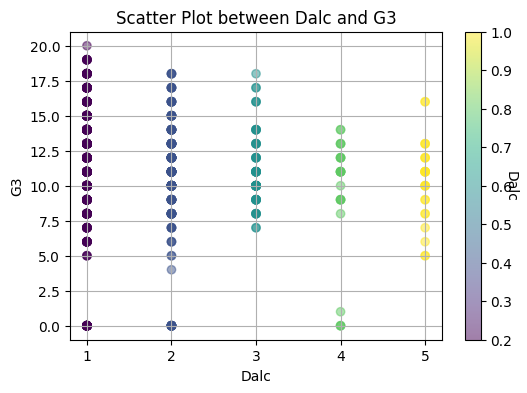
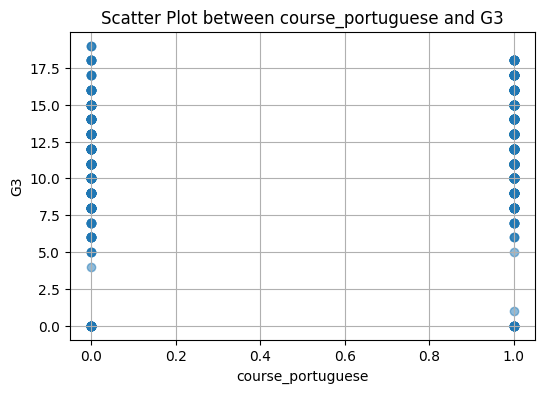
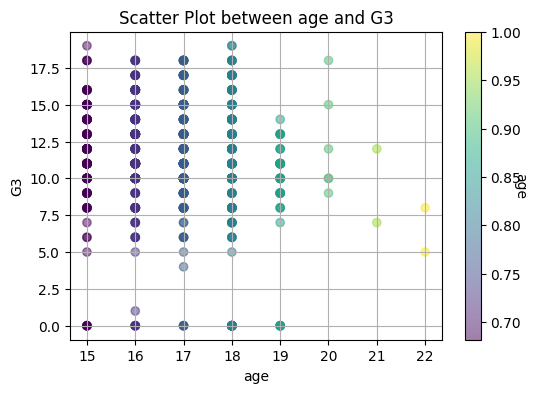
1-(3) Using the preprocessed data, find the top 10 input variables that show the high linear correlation with the target based on the correlation coefficients. (6pts)

* failures, higher\_yes, Medu, Fedu, course\_portuguese, studytime. shcool\_MS, age, guardian\_other, reason\_reputation

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1-(4) Draw pairwise scatter plots – one scatter plot illustrates the pairwise relationship between one of input variables selected in Question 1-(3) and output target. Paste figures here. (5pts)



1-(5) Calculate the variance inflation factor (VIF) for each explanatory variable and summarize the values in a table. (6pts)

|  |  |
| --- | --- |
| **Variable names** | **VIF** |
| age | 1.38823 |
| Medu | 2.797083 |
| Fedu | 2.198711 |
| traveltime | 1.293246 |
| studytime | 1.257459 |
| failures | 1.393125 |
| famrel | 1.137178 |
| freetime | 1.251613 |
| goout | 1.417067 |
| Dalc | 1.848905 |
| Walc | 2.122693 |
| health | 1.136783 |
| absences | 1.218337 |
| G3 | 1.40642 |
| school\_MS | 1.60093 |
| sex\_M | 1.345492 |
| address\_U | 1.317693 |
| Pstatus\_T | 1.133178 |
| schoolsup\_yes | 1.153156 |
| famsup\_yes | 1.141389 |
| paid\_yes | 1.462653 |
| nursery\_yes | 1.090246 |
| higher\_yes | 1.256417 |
| internet\_yes | 1.251754 |
| romantic\_yes | 1.10933 |
| course\_portuguese | 1.549223 |
| Mjob\_health | 1.810842 |
| Mjob\_other | 2.313649 |
| Mjob\_services | 2.380268 |
| Mjob\_teacher | 2.54197 |
| Fjob\_health | 1.775319 |
| Fjob\_other | 4.83393 |
| Fjob\_services | 4.368342 |
| Fjob\_teacher | 2.218724 |
| reason\_home | 1.327305 |
| reason\_other | 1.226275 |
| reason\_reputation | 1.353876 |
| guardian\_mother | 1.430375 |
| guardian\_other | 1.626558 |

* Almost every variables except ‘Fjob\_others’ and ‘Fjob\_services’ have low multicollinearity. For two variables, they exceeds VIF value by 4, so it has possibility of having multicollinearity.

1-(6) According to the results of Question 1-(5), describe your opinion on which variables should be excluded from training a linear regression model. Only in this assignment, if the VIF is 4 or greater, the multicollinearity is considered to be severe. (6pts)

* 'Fjob\_other' has to be excluded since it has the highest VIF value at about 4.84. After it is excluded, VIF of 'Fjob\_teacher' is decreased so the latter value does not necessarily be excluded.

**Part 2: Modeling**

2-(1) Train a linear regression model (**M1**) using all variables and fill the following table (You should add more rows to include all variables in the following table). (5pts)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Coefficient () |  |  | p-value |
| Intercept | 6.769836053 | 2.301893265 | 2.940986081 | 0.00337633 |
| age | 0.088556648 | 0.114256283 | 0.775070265 | 0.438551906 |
| Medu | 0.178568166 | 0.182317289 | 0.979436275 | 0.327692528 |
| Fedu | 0.09280206 | 0.161970706 | 0.572955831 | 0.56685299 |
| traveltime | 0.015278547 | 0.181454844 | 0.084200271 | 0.932920543 |
| studytime | 0.311289438 | 0.159103307 | 1.956523996 | 0.050788566 |
| failures | -1.283211728 | 0.206145308 | -6.224792301 | 8.17455E-10 |
| famrel | 0.352765415 | 0.134150338 | 2.629627477 | 0.00872985 |
| freetime | 0.182380937 | 0.13332558 | 1.367936574 | 0.171757521 |
| goout | -0.315549485 | 0.124800916 | -2.528422829 | 0.011669641 |
| Dalc | -0.05352637 | 0.181785528 | -0.294447919 | 0.768500291 |
| Walc | 0.042869992 | 0.136322655 | 0.314474452 | 0.753251568 |
| health | -0.263711646 | 0.089339739 | -2.951784381 | 0.003261854 |
| absences | 0.008452309 | 0.019902912 | 0.424677007 | 0.671198669 |
| school\_MS | -1.044376929 | 0.34766206 | -3.004000292 | 0.0027567 |
| sex\_M | -0.163183865 | 0.284402344 | -0.573778199 | 0.566296591 |
| address\_U | 0.169031851 | 0.31030195 | 0.544733447 | 0.586105065 |
| Pstatus\_T | -0.495267769 | 0.396788649 | -1.248190366 | 0.212365972 |
| schoolsup\_yes | -1.254233184 | 0.403956889 | -3.104868904 | 0.001978046 |
| famsup\_yes | -0.248473603 | 0.264228555 | -0.940373771 | 0.347340375 |
| paid\_yes | 0.050105808 | 0.360982052 | 0.138804153 | 0.889643618 |
| nursery\_yes | -0.101294551 | 0.308036352 | -0.328839599 | 0.742372288 |
| higher\_yes | 2.120588192 | 0.470083315 | 4.511090111 | 7.52637E-06 |
| internet\_yes | 0.140613991 | 0.326401311 | 0.430800938 | 0.666741695 |
| romantic\_yes | -0.844902617 | 0.263387777 | -3.207827734 | 0.001396468 |
| course\_portuguese | 1.884551538 | 0.303720398 | 6.204889604 | 9.21957E-10 |
| Mjob\_health | 1.527443209 | 0.634468958 | 2.407435683 | 0.016314893 |
| Mjob\_other | 0.311461694 | 0.374878831 | 0.830832973 | 0.406342651 |
| Mjob\_services | 0.688783199 | 0.441927083 | 1.55859015 | 0.119531618 |
| Mjob\_teacher | 0.347614485 | 0.578483494 | 0.600906488 | 0.548090864 |
| Fjob\_health | 0.238245202 | 0.852794706 | 0.279369936 | 0.780040949 |
| Fjob\_other | -0.049499515 | 0.533512098 | -0.092780493 | 0.926103687 |
| Fjob\_services | -0.310652545 | 0.558471394 | -0.556255071 | 0.578208845 |
| Fjob\_teacher | 1.024550616 | 0.768054338 | 1.3339559 | 0.182638926 |
| reason\_home | 0.399827801 | 0.324489355 | 1.232175399 | 0.218284685 |
| reason\_other | 0.210862115 | 0.45303724 | 0.46544102 | 0.641756022 |
| reason\_reputation | 0.433082026 | 0.334144202 | 1.296093193 | 0.195357528 |
| guardian\_mother | -0.599790123 | 0.31501013 | -1.9040344 | 0.057302977 |
| guardian\_other | -1.035098957 | 0.592236403 | -1.747780027 | 0.08092721 |

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2-(2) Train a linear regression model (**M2**) using the selected variables in Question 1-(3) and fill the following table (You should add more rows to include the selected variables in the following table). (5pts)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Coefficient () |  |  | p-value |
| Intercept | 5.729305095 | 1.970948431 | 2.906877219 | 0.003758213 |
| failures | -1.40185841 | 0.203443311 | -6.890658635 | 1.17757E-11 |
| higher\_yes | 2.133627769 | 0.468250383 | 4.556595886 | 6.06761E-06 |
| Medu | 0.347164639 | 0.150273635 | 2.31021655 | 0.021146742 |
| Fedu | 0.134870054 | 0.149402391 | 0.902730221 | 0.366958922 |
| course\_portuguese | 1.818379339 | 0.266649052 | 6.819372968 | 1.88267E-11 |
| studytime | 0.314788319 | 0.151063982 | 2.0838079 | 0.037515625 |
| school\_MS | -1.131269462 | 0.301710141 | -3.749524161 | 0.000190807 |
| romantic\_yes | -0.74768966 | 0.260299494 | -2.872420723 | 0.004188385 |
| age | 0.097875287 | 0.109772043 | 0.891623082 | 0.37288095 |
| guardian\_other | -0.444583024 | 0.514357605 | -0.864346166 | 0.387674109 |

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2-(3) Train a linear regression model (**M3**) using the selected variables in Question 1-(6) and fill the following table (You can add more rows to include the selected variables in the following table). (5pts)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Coefficient () |  |  | p-value |
| Intercept | 6.723295608 | 2.245032394 | 2.994743249 | 0.002840543 |
| age | 0.089209714 | 0.113961048 | 0.782808829 | 0.433995704 |
| Medu | 0.178570282 | 0.182192246 | 0.980120096 | 0.327354687 |
| Fedu | 0.092356197 | 0.161788363 | 0.570845736 | 0.568281595 |
| traveltime | 0.013543663 | 0.180365036 | 0.075090291 | 0.940163644 |
| studytime | 0.311286411 | 0.158994183 | 1.957847792 | 0.050632128 |
| failures | -1.283287452 | 0.20600231 | -6.229480887 | 7.94013E-10 |
| famrel | 0.352365572 | 0.133989139 | 2.629806965 | 0.008725035 |
| freetime | 0.182572447 | 0.133218171 | 1.370477063 | 0.170963373 |
| goout | -0.31567452 | 0.124708051 | -2.531308271 | 0.011574633 |
| Dalc | -0.053073333 | 0.181595306 | -0.292261591 | 0.770170469 |
| Walc | 0.042073806 | 0.13595898 | 0.309459555 | 0.757061137 |
| health | -0.263897575 | 0.089256003 | -2.956636709 | 0.003211435 |
| absences | 0.008530767 | 0.019871302 | 0.429300833 | 0.667832207 |
| school\_MS | -1.03894591 | 0.342463691 | -3.033740322 | 0.002501935 |
| sex\_M | -0.16287315 | 0.284187583 | -0.573118458 | 0.566742692 |
| address\_U | 0.171103957 | 0.309284935 | 0.553224348 | 0.580280817 |
| Pstatus\_T | -0.49576065 | 0.396480975 | -1.250402116 | 0.211557225 |
| schoolsup\_yes | -1.252627227 | 0.403309079 | -3.10587411 | 0.00197132 |
| famsup\_yes | -0.246901499 | 0.263503849 | -0.936993899 | 0.349074574 |
| paid\_yes | 0.049884595 | 0.360726606 | 0.138289202 | 0.890050365 |
| nursery\_yes | -0.098745683 | 0.306598447 | -0.32206844 | 0.747493946 |
| higher\_yes | 2.118970386 | 0.469437625 | 4.513848643 | 7.43018E-06 |
| internet\_yes | 0.140252278 | 0.326154182 | 0.430018334 | 0.667310442 |
| romantic\_yes | -0.845080649 | 0.263200149 | -3.210790917 | 0.001382269 |
| course\_portuguese | 1.88399332 | 0.303452535 | 6.208527204 | 9.01299E-10 |
| Mjob\_health | 1.523351776 | 0.632500519 | 2.408459329 | 0.016269239 |
| Mjob\_other | 0.306405528 | 0.37064227 | 0.826688028 | 0.408686645 |
| Mjob\_services | 0.686145762 | 0.440709408 | 1.556911989 | 0.119928983 |
| Mjob\_teacher | 0.343647268 | 0.576505372 | 0.596086844 | 0.551303779 |
| Fjob\_health | 0.282667021 | 0.705224617 | 0.400818426 | 0.688672231 |
| Fjob\_services | -0.266722274 | 0.295940851 | -0.901268863 | 0.367745507 |
| Fjob\_teacher | 1.069865909 | 0.592349074 | 1.806140933 | 0.071312063 |
| reason\_home | 0.398593746 | 0.323994278 | 1.230249335 | 0.219003879 |
| reason\_other | 0.208880454 | 0.452223113 | 0.4618969 | 0.644294206 |
| reason\_reputation | 0.432323843 | 0.33381516 | 1.295099487 | 0.195699305 |
| guardian\_mother | -0.602081461 | 0.313825176 | -1.91852505 | 0.055437963 |
| guardian\_other | -1.036474742 | 0.591644683 | -1.751853388 | 0.080222974 |
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2-(4) Describe difference between M1, M2, and M3 based on the tables of Question 2-(1), (2), and (3). (5pts)

* For M2 model, it has only 10 variable while M1 and M3 has 38, 37 variables, respectively. As a result, it shows slightly different output compared to M1 or M3.
* For M1 and M3, M3 model has one less variable than M1 so they have slightly different result.

**Part 3: Assessment**

3-(1) Apply the F-test on M1, M2, and M3 and explain the results. In addition, fill the following tables. (7pts)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| M1 | SS | Degree of freedom | MS | F | p-value |
| Model | 3242.266481 | 38 | 85.32280213 | 7.721971933 | 1.11022E-16 |
| Residual | 7977.63365 | 722 | 11.04935409 |  |  |
| Total | 11219.90013 | 760 | 10.49688638 |  |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| M2 | SS | Degree of freedom | MS | F | p-value |
| Model | 2660.173026 | 10 | 266.0173026 | 23.30833384 | 1.11022E-16 |
| Residual | 8559.727106 | 750 | 11.41296947 |  |  |
| Total | 11219.90013 | 760 | 11.26279882 |  |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| M3 | SS | Degree of freedom | MS | F | p-value |
| Model | 3242.171366 | 37 | 87.62625313 | 7.941330531 | 1.11022E-16 |
| Residual | 7977.728766 | 723 | 11.034203 |  |  |
| Total | 11219.90013 | 760 | 10.49701153 |  |  |

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3-(2) Calculate and for M1, M2 and M3. Then, compare these models. (4pts)

Model M1:

R-squared: 0.2889746292870229

Adjusted R-squared: 0.25155224135476095

Model M2:

R-squared: 0.2370941804029194

Adjusted R-squared: 0.22692210280829161

Model M3:

R-squared: 0.2889661519148162

Adjusted R-squared: 0.2525785276006367

* Models M1 and M3 have similar explanatory power, while Model M2 has the lowest explanatory power. The Adjusted R-squared values confirm these findings, indicating the models' goodness of fit while considering the number of variables.
* However, the absolute sizes of the values are quite low, so they do not explain the dependent variable well.

3-(3) Considering the results of previous questions, suggest a better approach to select explanatory variables for the modeling. (5pts)

* To choose better variables that explain the dependent variable well, there’s need to test variables with t-test.

3-(4) Obtain the residual plots of M1, M2, and M3 (x-axis=predicted target values, y-axis=residuals) and assess the assumptions related to errors based on the plots. (6pts)

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* By checking the residual plots of models, we can assess the homoscedasticity of the residuals which indicates that the residuals should have the uniformed residual regardless of the variable. However, as we can see the plots, there are some tendency showing a pattern. It means that the model does not explain the data enough.

3-(5) Do residuals of M1, M2, and M3 follow the normal distribution based on the Jarque–Bera test? (significance level is 0.05). If residuals do not follow the normal distribution, what might be the cause? (7pts)

* In this case, I tried to find if those residuals follow the normal distribution, however, I found that there are significant difference of Jarque-Bera tests done by manually and by importing Jarque-Bera method.
* 1) Done by manually
  + Codes

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자동 생성된 설명

* + Result
  + 텍스트, 스크린샷, 폰트이(가) 표시된 사진

    자동 생성된 설명
* 2) Done by importing Jarque-Bera method
  + Codes

텍스트, 스크린샷, 폰트이(가) 표시된 사진

자동 생성된 설명

* + Result

텍스트, 스크린샷, 폰트이(가) 표시된 사진

자동 생성된 설명

* I tried to figure out the difference between two methods, unfortunately, I couldn’t. For the first method, the p-value is calculated as 0, so it does not have any mean since it can’t be zero. By using the second method, we can get to know that the p-values are bigger than 0.5, so we can conclude that they follow normal distribution.

**[2. Logistic regression (22pt)]**

Using the cardiovascular disease dataset, build a classifier using logistic regression.

The included variables in this dataset are as follows.

[Variables]

|  |  |
| --- | --- |
| **Variable name** | **Description** |
| **Cardio** | **Dependent variable, indicating the presence or absence of cardiovascular disease (binary: yes – presence, or no – absence)** |
| Age | Age of the individuals in years |
| Gender | Gender of the individuals (binary: “F”-female or “M”-male) |
| Height | Height of the individuals in centimeters (cm) |
| Weight | Weight of the individuals in kilograms (kg) |
| Ap\_hi | Systolic blood pressure of the individuals |
| Ap\_lo | Diastolic blood pressure of the individuals |
| Cholesterol | Cholesterol level of the individuals (ordinal: 1 – normal, 2 – above normal, or 3 – well above normal) |
| Gluc | Glucose level of the individuals (ordinal: 1 – normal, 2 – above normal, or 3 – well above normal) |
| Smoke | Indicates whether a person smokes (binary: yes or no) |
| Alco | Indicates whether a person consumes alcohol (binary: yes or no) |
| Active | Indicates whether a person engages in regular physical activities (binary: yes or no) |

(1) pre-process data. Some data samples have outliers for some variables, and they need to be properly addressed for accurate analysis. Implement box-plot-based outlier removal.

After removing outliers, split the whole dataset into training/test sets (8:2). Please maintain the same ratio of classes in both the training and test set. (3pts)

* (before excluding outliers)

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* (after excluding outliers)

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텍스트, 스크린샷이(가) 표시된 사진

자동 생성된 설명

(2) Train logistic regression models using the training samples (in x\_train) of each the explanatory variable (this will result in a total of 11 logistic regression models). After training, calculate the accuracy of each model using the validation set (in x\_valid). Which variable is the most important according to the accuracy? (5pts)

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* ap\_hi has the highest accuracy

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(3) Using the top two variables with the highest accuracy obtained for Question (1), train a logistic regression model on the training samples (in x\_train). Draw the decision boundary showing equal probability values for classes 0 and 1 (x-axis=the variable with the highest accuracy, y-axis = the variable with the second highest accuracy) with scatter plots of the samples used for the training (assign different colors depending on the predicted class for the scatter plot). (9pts)

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(4) Using the cardiovascular disease dataset, calculate accuracy with varying cutoff for the final decision (if the probability of 1 >= cutoff, the predicted target is 1). cutoff ∈{0.05, 0.1,0.15,0.2,0.25,…,0.95}. Draw a line plot (x=cutoff, y=accuracy). For this problem, the model is trained using x\_train including all explanatory variables and accuracy is calculated using x\_valid. (5pts)

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