# PREDICTIVE MODELLING PROJECT BUSINESS REPORT

DSBA

*Written by*

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# Contents

## Problem 1: Linear Regression

The comp-activ databases is a collection of a computer systems activity measures .
The data was collected from a Sun Sparcstation 20/712 with 128 Mbytes of memory running in a multi-user university department. Users would typically be doing a large variety of tasks ranging from accessing the internet, editing files or running very cpu-bound programs.

As you are a budding data scientist you thought to find out a linear equation to build a model to predict 'usr'(Portion of time (%) that cpus run in user mode) and to find out how each attribute affects the system to be in 'usr' mode using a list of system attributes.

### 1.1 Read the data and do exploratory data analysis. Describe the data briefly. (Check the Data types, shape, EDA, 5-point summary). Perform Univariate, Bivariate Analysis, Multivariate Analysis.

i. Head of the data (the first five rows):

| | lread | lwrite | scall | sread | swrite | fork | exec | rchar | wchar | pgout | ... | pgscan | atch | pgin | ppgin | pflt | vflt | runqsz | freemem | freesv |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 1 | 0 | 2147 | 79 | 68 | 0.2 | 0.2 | 40671.0 | 53995.0 | 0.0 | ... | 0.0 | 0.0 | 1.6 | 2.6 | 16.00 | 26.40 | CPU_Bound | 4670 | 1730 |
| **1** | 0 | 0 | 170 | 18 | 21 | 0.2 | 0.2 | 448.0 | 8385.0 | 0.0 | ... | 0.0 | 0.0 | 0.0 | 0.0 | 15.63 | 16.83 | Not_CPU_Bound | 7278 | 1869 |
| **2** | 15 | 3 | 2162 | 159 | 119 | 2.0 | 2.4 | NaN | 31950.0 | 0.0 | ... | 0.0 | 1.2 | 6.0 | 9.4 | 150.20 | 220.20 | Not_CPU_Bound | 702 | 1021 |
| **3** | 0 | 0 | 160 | 12 | 16 | 0.2 | 0.2 | NaN | 8670.0 | 0.0 | ... | 0.0 | 0.0 | 0.2 | 0.2 | 15.60 | 16.80 | Not_CPU_Bound | 7248 | 1863 |
| **4** | 5 | 1 | 330 | 39 | 38 | 0.4 | 0.4 | NaN | 12185.0 | 0.0 | ... | 0.0 | 0.0 | 1.0 | 1.2 | 37.80 | 47.60 | Not_CPU_Bound | 633 | 1760 |

5 rows × 22 columns

ii. The compactiv dataset has 8192 rows and 22 columns.
iii. Null values: ‘rchar’ has 104 null values while ‘wchar’ has 15 null values.
iv. No duplicates found in the dataset.
v. The info on the dataset is as follows: 13 *float64* datatype, 8 *int64* datatype, 1 *object* datatype variables.
vi. The 5-point-summary (min, 25%, 50%, 75%, max) of each variable is given below through data description:

| | count | mean | std | min | 25% | 50% | 75% | max |
|---|---|---|---|---|---|---|---|---|
| **lread** | 8192.0 | 1.955969e+01 | 53.353799 | 0.0 | 2.0 | 7.0 | 20.000 | 1845.00 |
| **lwrite** | 8192.0 | 1.310620e+01 | 29.891726 | 0.0 | 0.0 | 1.0 | 10.000 | 575.00 |
| **scall** | 8192.0 | 2.306318e+03 | 1633.617322 | 109.0 | 1012.0 | 2051.5 | 3317.250 | 12493.00 |
| **sread** | 8192.0 | 2.104800e+02 | 198.980146 | 6.0 | 86.0 | 166.0 | 279.000 | 5318.00 |
| **swrite** | 8192.0 | 1.500582e+02 | 160.478980 | 7.0 | 63.0 | 117.0 | 185.000 | 5456.00 |
| **fork** | 8192.0 | 1.884554e+00 | 2.479493 | 0.0 | 0.4 | 0.8 | 2.200 | 20.12 |
| **exec** | 8192.0 | 2.791998e+00 | 5.212456 | 0.0 | 0.2 | 1.2 | 2.800 | 59.56 |
| **rchar** | 8088.0 | 1.973857e+05 | 239837.493526 | 278.0 | 34091.5 | 125473.5 | 267828.750 | 2526649.00 |
| **wchar** | 8177.0 | 9.590299e+04 | 140841.707911 | 1498.0 | 22916.0 | 46619.0 | 106101.000 | 1801623.00 |
| **pgout** | 8192.0 | 2.285317e+00 | 5.307038 | 0.0 | 0.0 | 0.0 | 2.400 | 81.44 |
| **ppgout** | 8192.0 | 5.977229e+00 | 15.214590 | 0.0 | 0.0 | 0.0 | 4.200 | 184.20 |
| **pgfree** | 8192.0 | 1.191971e+01 | 32.363520 | 0.0 | 0.0 | 0.0 | 5.000 | 523.00 |
| **pgscan** | 8192.0 | 2.152685e+01 | 71.141340 | 0.0 | 0.0 | 0.0 | 0.000 | 1237.00 |
| **atch** | 8192.0 | 1.127505e+00 | 5.708347 | 0.0 | 0.0 | 0.0 | 0.600 | 211.58 |
| **pgin** | 8192.0 | 8.277960e+00 | 13.874978 | 0.0 | 0.6 | 2.8 | 9.765 | 141.20 |
| **ppgin** | 8192.0 | 1.238859e+01 | 22.281318 | 0.0 | 0.6 | 3.8 | 13.800 | 292.61 |
| **pflt** | 8192.0 | 1.097938e+02 | 114.419221 | 0.0 | 25.0 | 63.8 | 159.600 | 899.80 |
| **vflt** | 8192.0 | 1.853158e+02 | 191.000603 | 0.2 | 45.4 | 120.4 | 251.800 | 1365.00 |
| **freemem** | 8192.0 | 1.763456e+03 | 2482.104511 | 55.0 | 231.0 | 579.0 | 2002.250 | 12027.00 |
| **freeswap** | 8192.0 | 1.328126e+06 | 422019.426957 | 2.0 | 1042623.5 | 1289289.5 | 1730379.500 | 2243187.00 |
| **usr** | 8192.0 | 8.396887e+01 | 18.401905 | 0.0 | 81.0 | 89.0 | 94.000 | 99.00 |

vii. The null values in 'rchar' and 'wchar' have been replaced with median of the respective features.

viii. Value counts of the target variable 'runqsz' is given below:

```
Not_CPU_Bound    4331
CPU_Bound        3861
Name: runqsz, dtype: int64
```

These values have been replaced as 0 and 1 to give them numeric values. Not_CPU_Bound has been assigned 0 and CPU_Bound has been assigned 1.

**ix. Univariate analysis:**

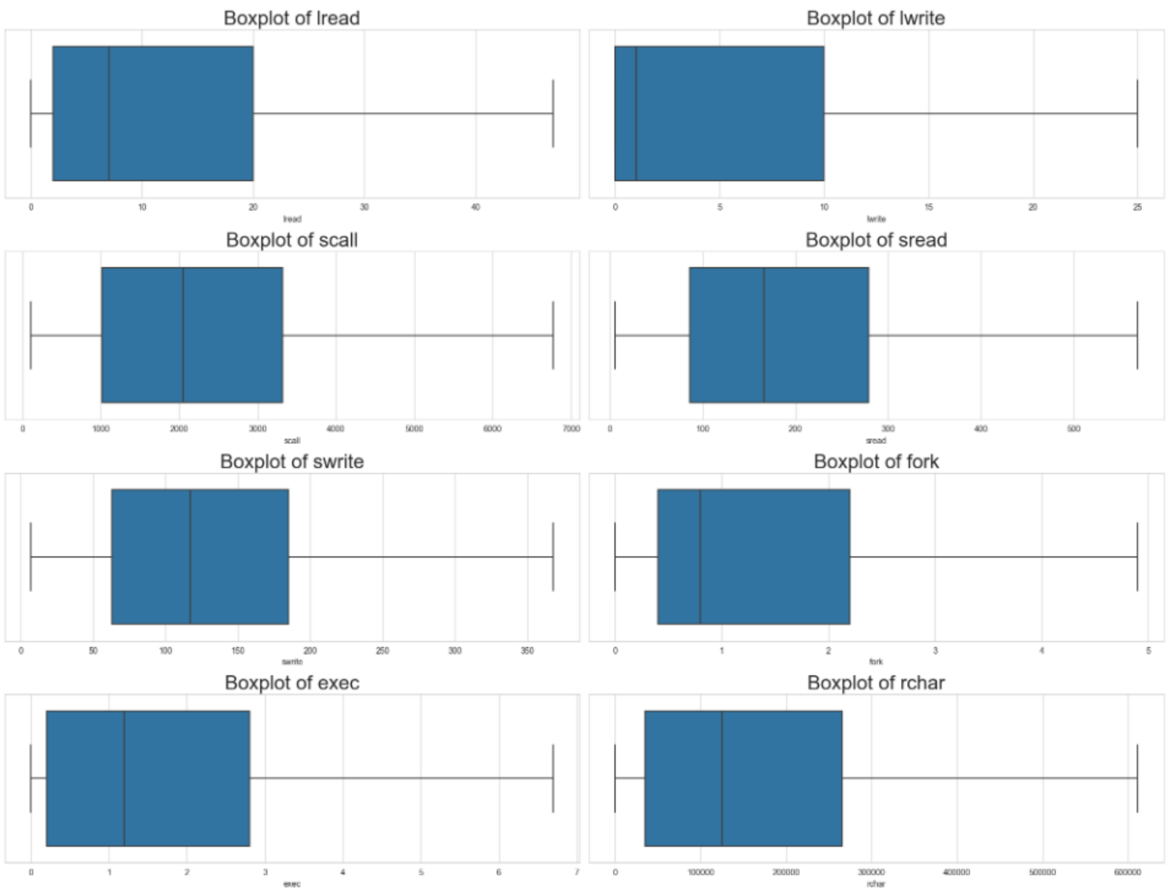
- Before analysing the dataset, I have checked for outliers and treated them with the help of the IQR method. I have replaced outliers with lower and upper range values that the formulae <u>upper range=Q3+(1.5*IQR)</u> and <u>lower range=Q1-(1.5*IQR)</u> give as output.

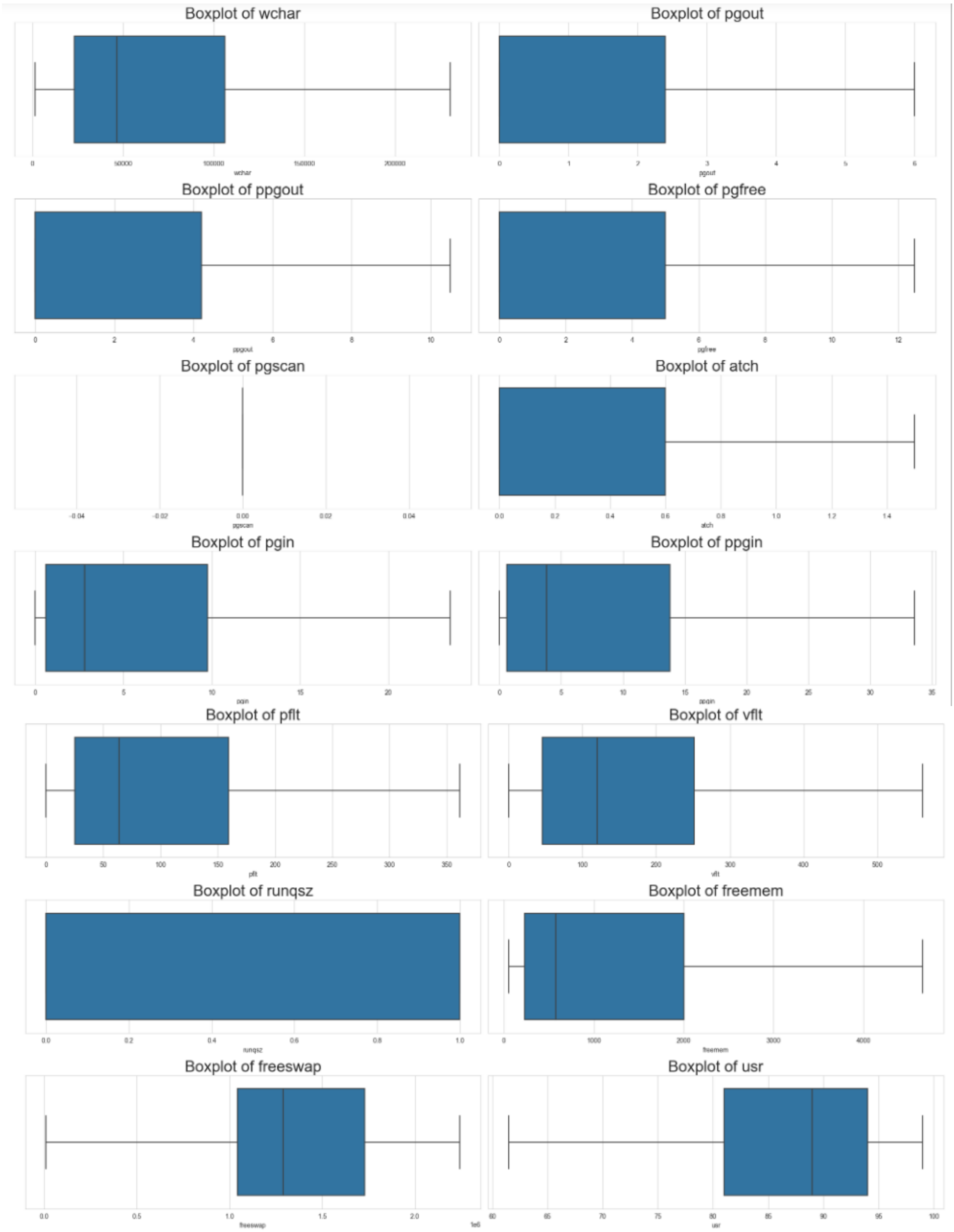
- Following are the 0 values present in each feature:

```
lread: 675
lwrite: 2684
scall: 0
sread: 0
swrite: 0
fork: 21
exec: 21
rchar: 0
wchar: 0
pgout: 4878
ppgout: 4878
pgfree: 4869
pgscan: 8192
atch: 4575
pgin: 1220
ppgin: 1220
pflt: 3
vflt: 0
runqsz: 4331
freemem: 0
freeswap: 0
```

- After treating outliers, there are 8192 zero values in ‘pgscan’, hence I dropped this column.

- Following is the boxplot distribution of each variable via boxplot:

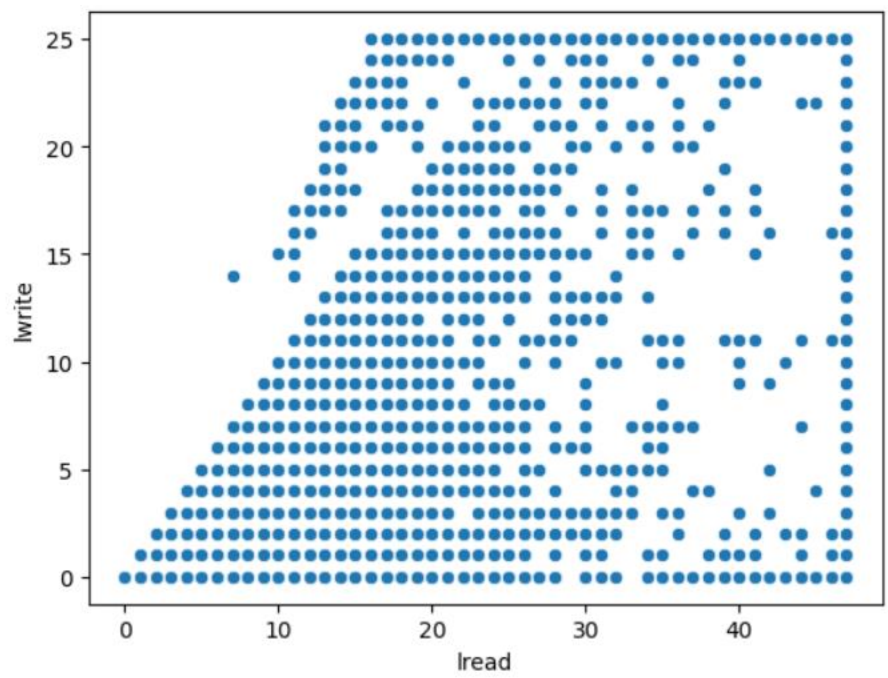




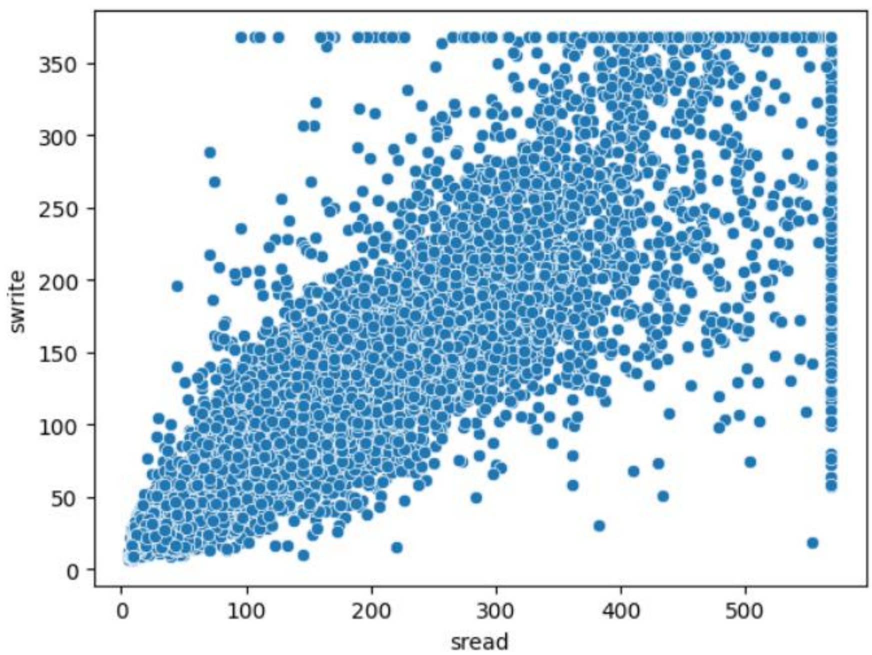

All the variable distributions in the above figures are right-skewed, except the last two, i.e., ‘freeswap’ and ‘usr’, which are left-skewed.

**x. Bivariate Analysis:**

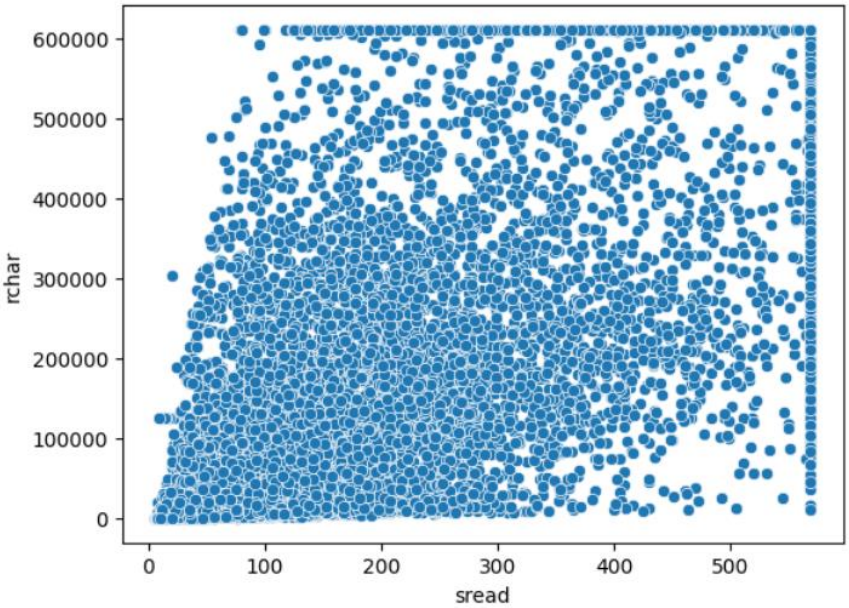
- ‘lread’ versus ‘lwrite’



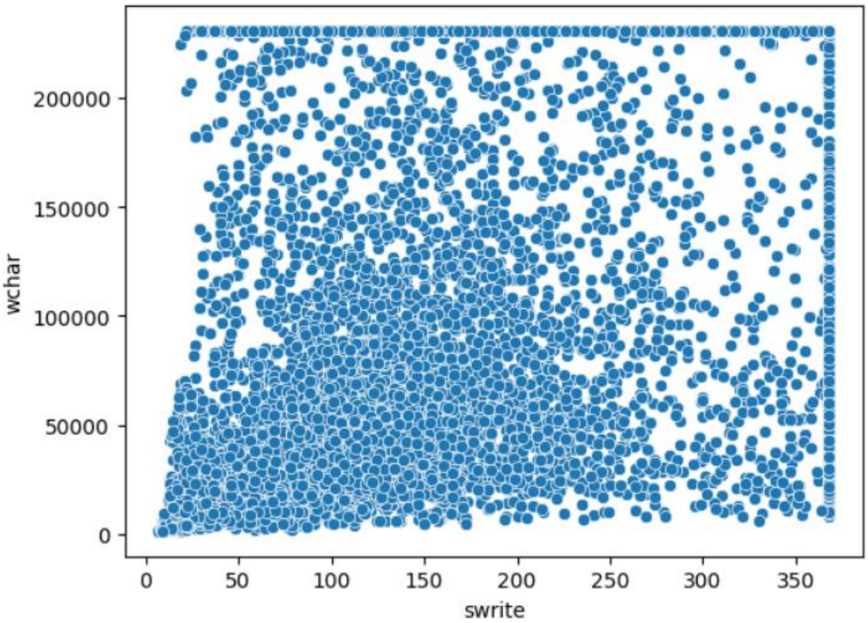

- 'sread' versus 'swrite'



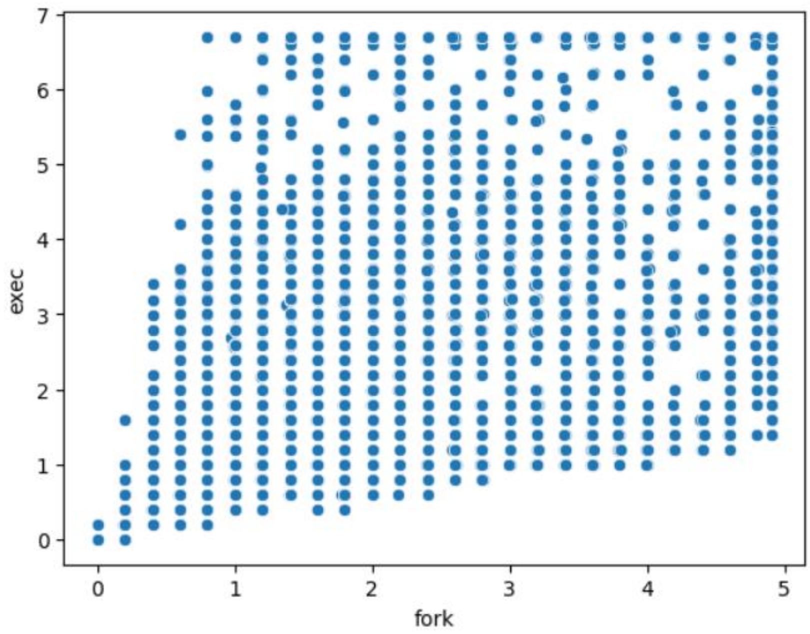
- 'sread' versus 'rchar'



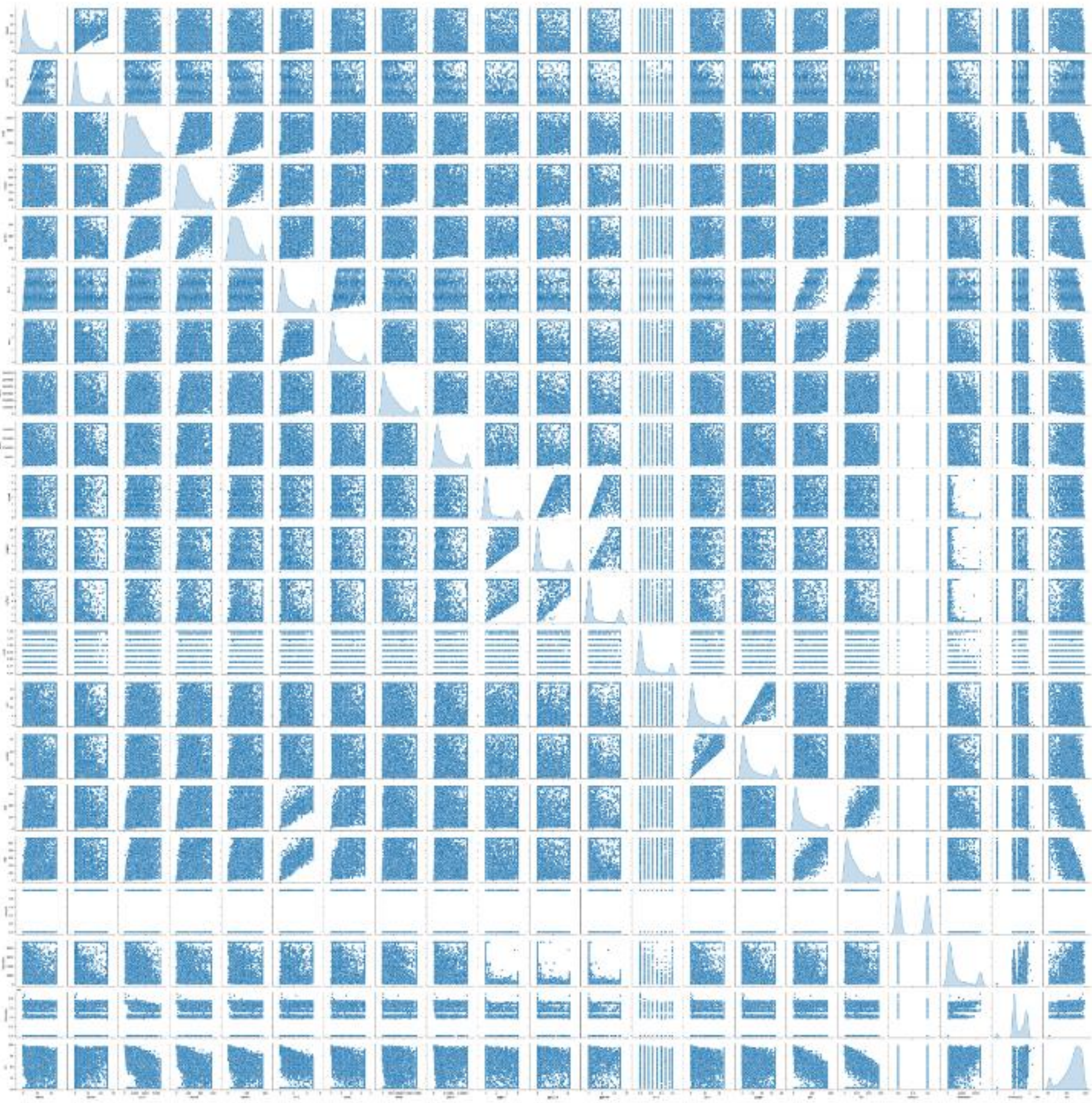

- 'swrite' versus 'wchar'

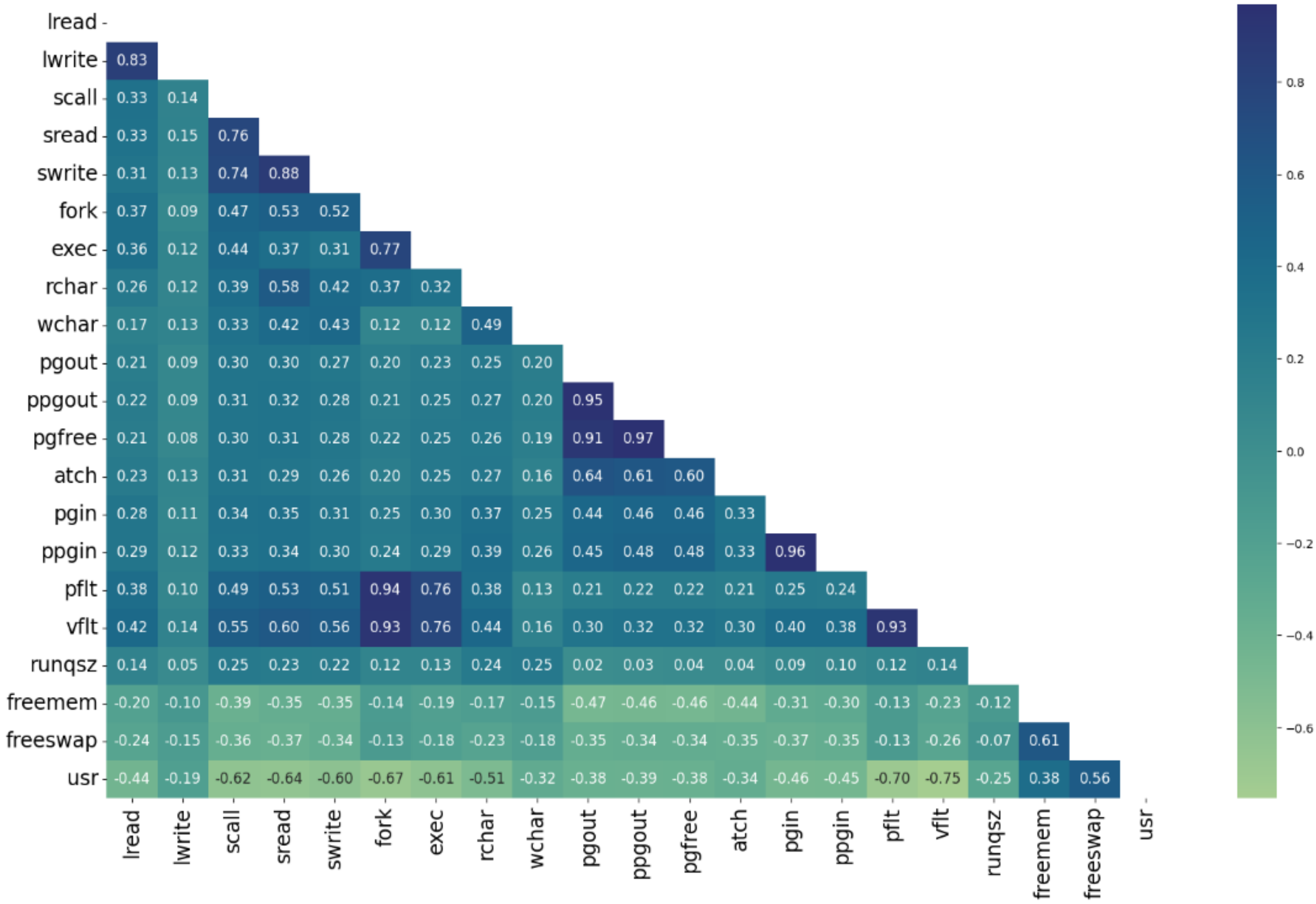


- ‘fork’ versus ‘exec’




- The above scatterplots indicate some correlation between variables but to be sure, we need to look at the pairplot as well as the correlation heatmap of the dataset. Sample screenshot given below:



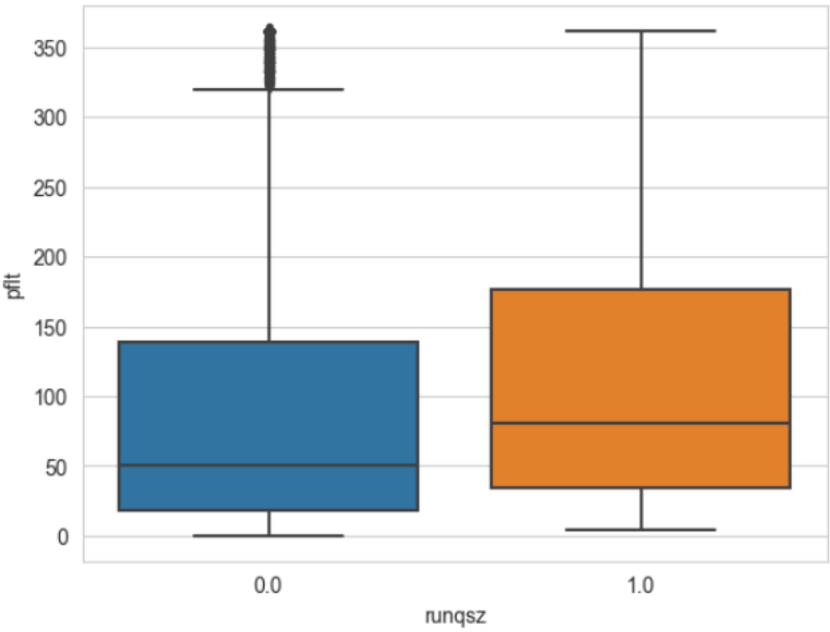


- Following pairs show a strong correlation from the above graphs:
  a. pgin, ppgin – 0.96
  b. pflt, vflt – 0.93
  c. fork, pflt – 0.94
  d. fork, vflt – 0.93
  e. sread, swrite – 0.88
  f. lread, lwrite – 0.83
  g. fork, exec – 0.77
  h. ppgout, pgfree – 0.97
  i. ppgout, pgout – 0.95
  j. scall, sread – 0.76
  k. scall, swrite – 0.74

- Since ‘usr’ is our target variable, we can spot many strong inverse correlations between ‘usr’ and other variables like ‘vflt’, ‘pflt’, ‘fork’, and ‘sread’.

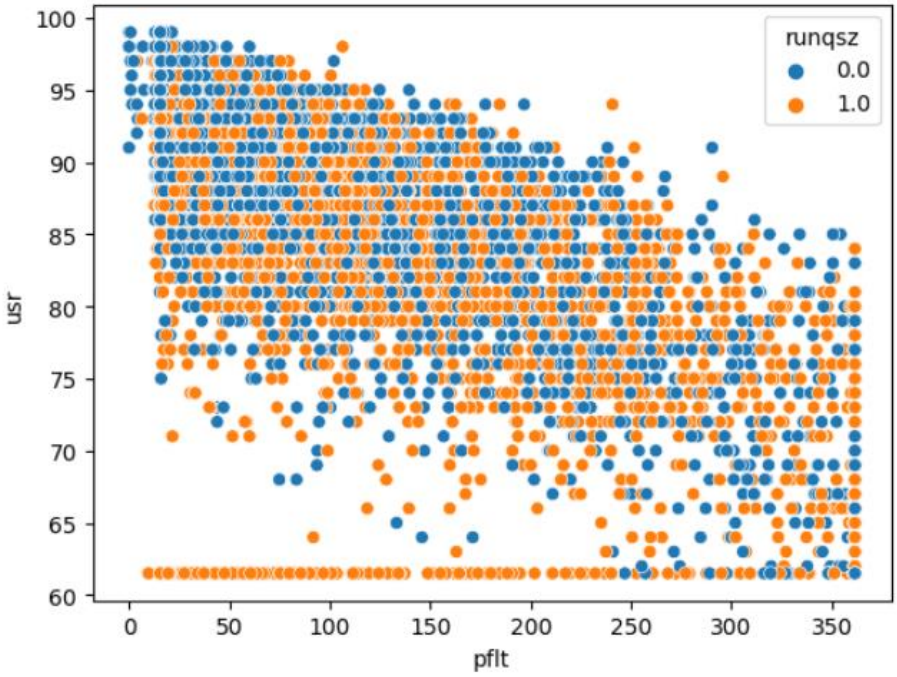
- To reduce ‘usr’, we need to investigate the cause of increase in pflt.
- To investigate this further, I plotted a boxplot by keeping ‘runqsz’ in the x-axis and ‘pflt’.
- The below boxplot shows that the average ‘pflt’ is higher in CPU_Bound (1) records than in Not_CPU_Bound (0) records.

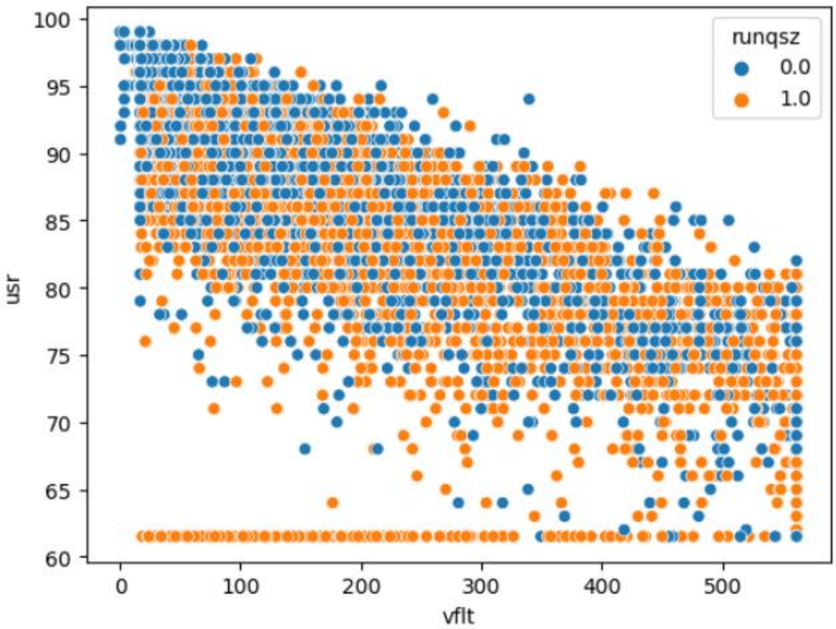
```
runqsz
0.0     93.738677
1.0    118.981735
Name: pflt, dtype: float64
```




**xi. Multivariate Analysis:**

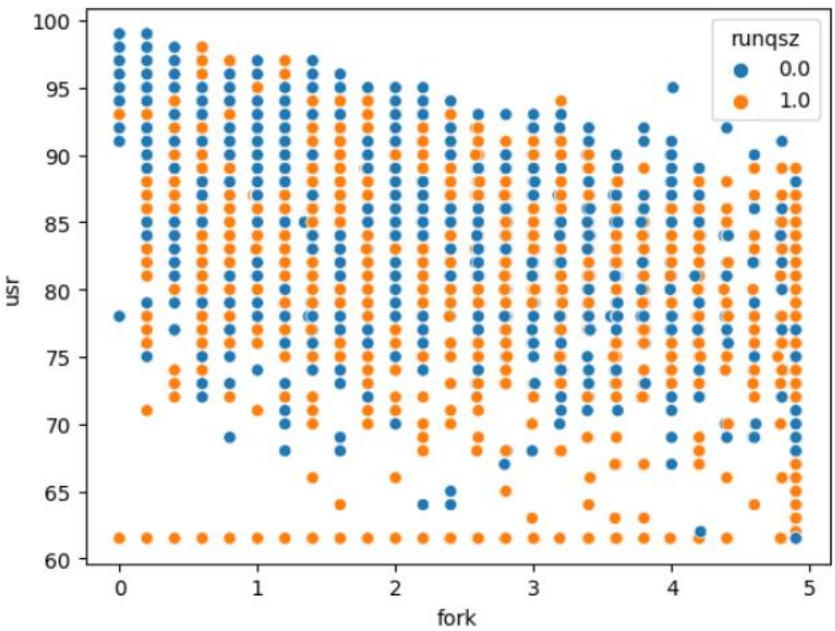
- Building on the bivariate analysis, I went one step further to analyse ‘usr’ against ‘pflt’/’vflt’, with ‘runqsz’ as hue:






*Both, ‘pflt’ and ‘vflt’ against ‘usr’ show an inversely correlated pattern for both, 0 and 1 classes of ‘runqsz’ with little difference in pattern.*

- Scatterplot with ‘fork’ and ‘exec’ on the axis and ‘runqsz’ as hue:

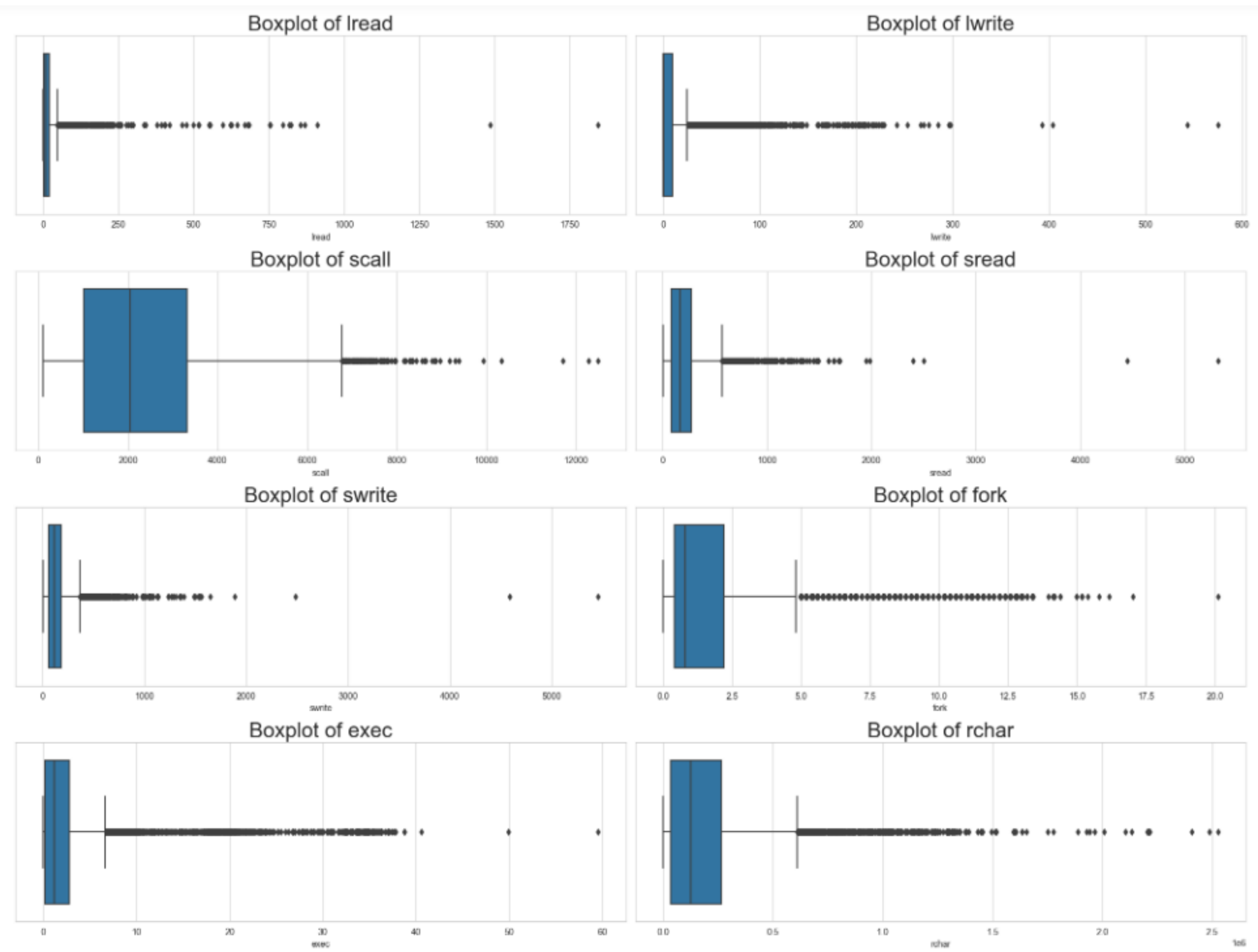


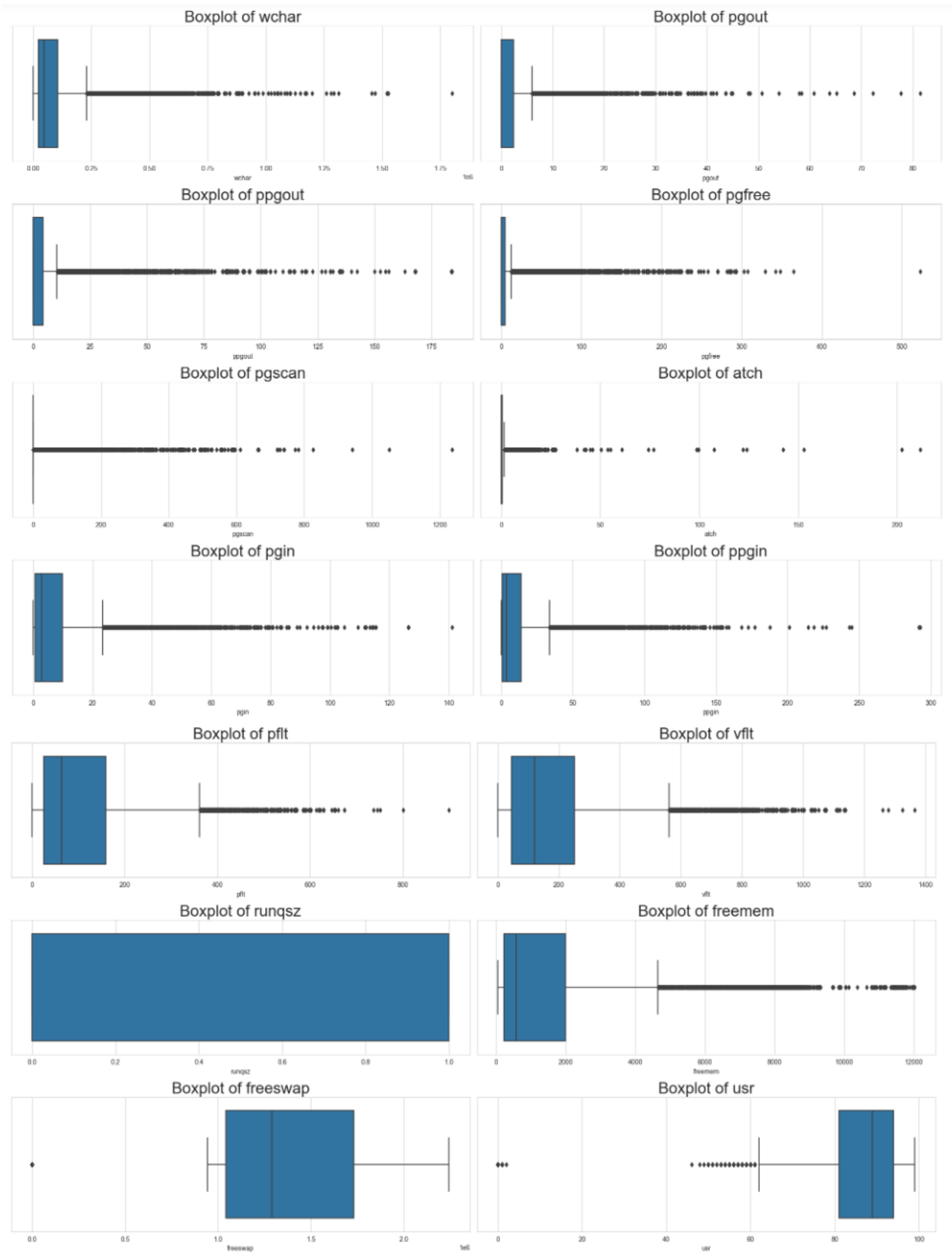

*F*

*Even for ‘usr’ versus ‘fork’, no pattern relating to ‘runqsz’ classes found.*

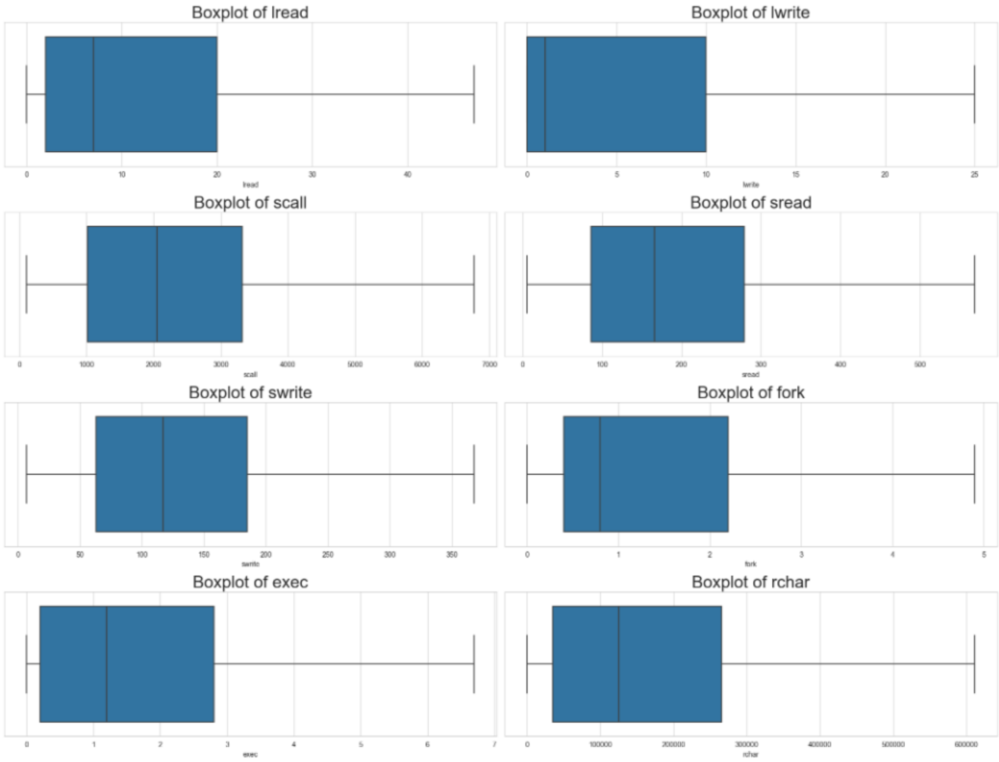
## 1.2 Impute null values if present, also check for the values which are equal to zero. Do they have any meaning or do we need to change them or drop them? Check for the possibility of creating new features if required. Also check for outliers and duplicates if there.

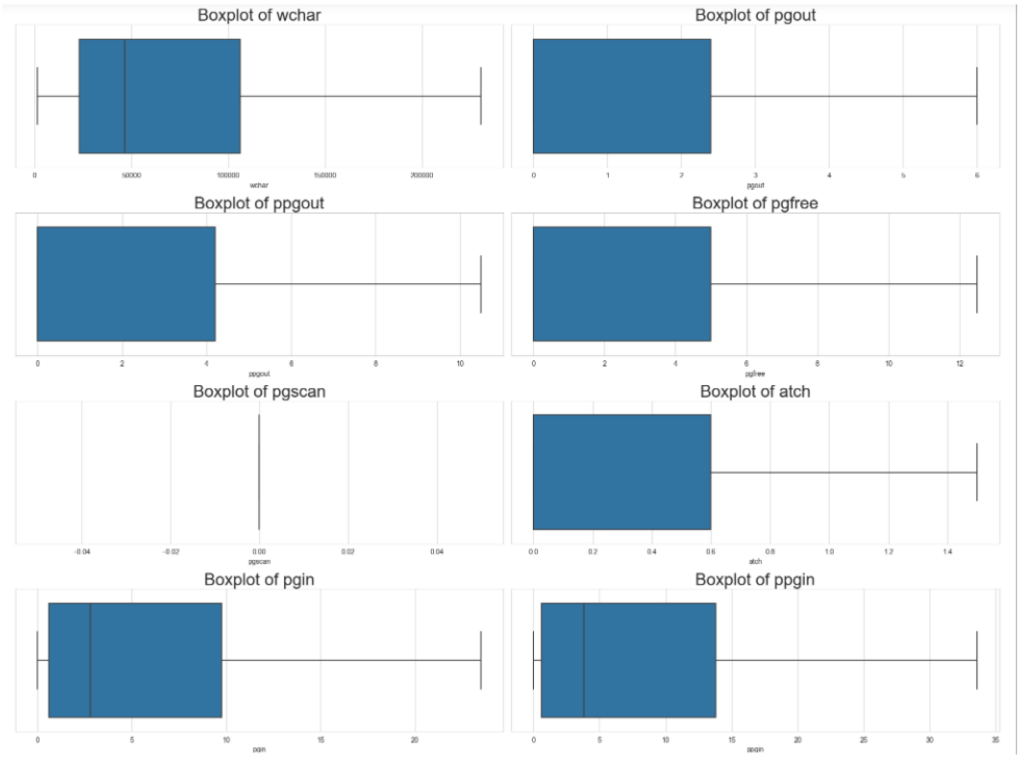
i. Null values already imputed with median for columns ‘rchar’ and ‘wchar’.
ii. No duplicates were found.
iii. ‘pgscan’ variable has been dropped because all the values in this columns came to a 0 after treating outliers. Even pre-outlier treatment, about 78% of the ‘pgscan’ values were 0. Due to this reason, I made the decision to drop it.
iv. No new features created/required yet.
v. Outliers have been checked and treated. Snapshot given below:

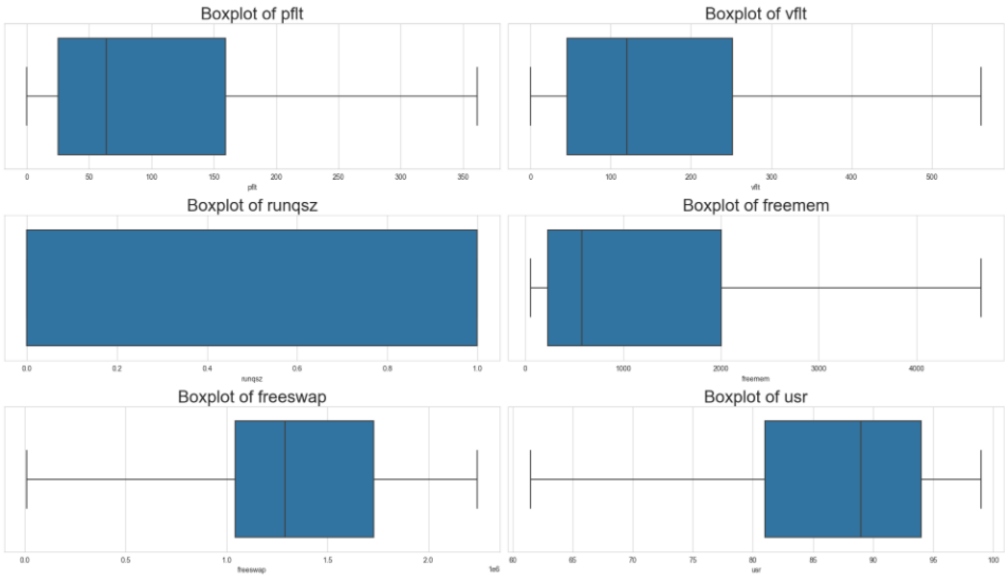





vi. After the treatment of outliers, the boxplots look like this:


Boxplot of lread
Boxplot of lwrite
Boxplot of scall
Boxplot of sread
Boxplot of swrite
Boxplot of fork
Boxplot of exec
Boxplot of rchar


Boxplot of wchar
Boxplot of pgout
Boxplot of ppgout
Boxplot of pgfree
Boxplot of pgscan
Boxplot of atch
Boxplot of pgin
Boxplot of ppgin




vii. ‘runqsz’ has been converted to numeric with values 0 and 1 already where ‘CPU_Bound’ is assigned the value of 1 and ‘Not_CPU_Bound’ is assigned 0.

## 1.3 Encode the data (having string values) for Modelling. Split the data into train and test (70:30). Apply Linear regression using scikit learn. Perform checks for significant variables using appropriate method from statsmodel. Create multiple models and check the performance of Predictions on Train and Test sets using Rsquare, RMSE & Adj Rsquare. Compare these models and select the best one with appropriate reasoning.

i. Initial model without any adjustments:

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                    usr   R-squared:                       0.793
Model:                            OLS   Adj. R-squared:                  0.792
Method:                 Least Squares   F-statistic:                     1093.
Date:                Sun, 05 Mar 2023   Prob (F-statistic):               0.00
Time:                        11:28:40   Log-Likelihood:                -16686.
No. Observations:                5734   AIC:                         3.341e+04
Df Residuals:                    5713   BIC:                         3.355e+04
Df Model:                          20
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         85.0494      0.298    285.844      0.000      84.466      85.633
lread         -0.0633      0.009     -7.147      0.000      -0.081      -0.046
lwrite         0.0456      0.013      3.517      0.000       0.020       0.071
scall         -0.0007   6.35e-05    -11.350      0.000      -0.001      -0.001
sread          0.0026      0.001      2.513      0.012       0.001       0.005
swrite        -0.0064      0.001     -4.423      0.000      -0.009      -0.004
fork          -0.0896      0.133     -0.672      0.502      -0.351       0.172
exec          -0.2494      0.051     -4.861      0.000      -0.350      -0.149
rchar      -4.983e-06   4.87e-07    -10.237      0.000   -5.94e-06   -4.03e-06
wchar      -5.196e-06   1.04e-06     -4.992      0.000   -7.24e-06   -3.16e-06
pgout         -0.4979      0.089     -5.575      0.000      -0.673      -0.323
ppgout        -0.0675      0.081     -0.837      0.403      -0.226       0.091
pgfree         0.1456      0.049      2.966      0.003       0.049       0.242
atch           0.5881      0.143      4.107      0.000       0.307       0.869
pgin           0.0518      0.029      1.778      0.076      -0.005       0.109
ppgin         -0.0846      0.020     -4.178      0.000      -0.124      -0.045
pflt          -0.0324      0.002    -16.409      0.000      -0.036      -0.029
vflt          -0.0062      0.001     -4.399      0.000      -0.009      -0.003
runqsz        -1.7242      0.126    -13.649      0.000      -1.972      -1.477
freemem       -0.0005   5.12e-05     -9.155      0.000      -0.001      -0.000
freeswap    9.223e-06   1.91e-07     48.401      0.000    8.85e-06     9.6e-06
==============================================================================
Omnibus:                      980.750   Durbin-Watson:                   2.022
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1932.140
Skew:                          -1.040   Prob(JB):                         0.00
Kurtosis:                       4.940   Cond. No.                     7.16e+06
==============================================================================
```

- In the initial model, we notice that the p-value for 'fork' and 'ppgout' is very high, followed by 'pgin' and 'sread'. The R-squared value is 0.793. Now we will go ahead and check the VIF (variance inflation factor) values for each variable to see how much multicollinearity has been brought by each feature.

```
VIF values:

const       25.629887
lread        5.222496
lwrite       4.230336
scall        2.987824
sread        6.555928
swrite       5.666273
fork        13.195160
exec         3.216047
rchar        2.088006
wchar        1.583353
pgout       11.215199
ppgout      30.947431
pgfree      17.468614
atch         1.848297
pgin        14.475734
ppgin       14.673035
pflt        11.703237
vflt        15.370510
runqsz       1.151214
freemem      1.974160
freeswap     1.847552
dtype: float64
```

- Since there are multiple features with higher than 10 VIF value, I have dropped one variable at a time and checked the R-squared for the model.
- R-squared and Adj. R-squared remained the same when ‘ppgout’, ‘pgin’ and ‘fork’ were dropped. This indicates that we can start by dropping these variables to check if the VIF values become suitable to build a better model.
- The value of R-squared and Adj. R-squared dropped by 0.009 when ‘pflt’ was dropped. This decline is relatively steep when compared to other variables. Hence, ‘pflt’ is concluded to be an important variable for the model.
- After dropping ‘ppgout’, this is the model as output:

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                    usr   R-squared:                       0.793
Model:                            OLS   Adj. R-squared:                  0.792
Method:                 Least Squares   F-statistic:                     1150.
Date:                Sun, 05 Mar 2023   Prob (F-statistic):               0.00
Time:                        11:28:41   Log-Likelihood:                -16687.
No. Observations:                5734   AIC:                         3.341e+04
Df Residuals:                    5714   BIC:                         3.355e+04
Df Model:                          19
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         85.0682      0.297    286.732      0.000      84.487      85.650
lread         -0.0634      0.009     -7.167      0.000      -0.081      -0.046
lwrite         0.0457      0.013      3.530      0.000       0.020       0.071
scall         -0.0007   6.35e-05    -11.347      0.000      -0.001      -0.001
sread          0.0026      0.001      2.505      0.012       0.001       0.005
swrite        -0.0065      0.001     -4.425      0.000      -0.009      -0.004
fork          -0.0870      0.133     -0.653      0.514      -0.348       0.174
exec          -0.2502      0.051     -4.877      0.000      -0.351      -0.150
rchar      -4.983e-06   4.87e-07    -10.237      0.000   -5.94e-06   -4.03e-06
wchar      -5.234e-06   1.04e-06     -5.033      0.000   -7.27e-06    -3.2e-06
pgout         -0.5473      0.067     -8.159      0.000      -0.679      -0.416
pgfree         0.1124      0.029      3.878      0.000       0.056       0.169
atch           0.5903      0.143      4.123      0.000       0.310       0.871
pgin           0.0531      0.029      1.823      0.068      -0.004       0.110
ppgin         -0.0856      0.020     -4.237      0.000      -0.125      -0.046
pflt          -0.0324      0.002    -16.409      0.000      -0.036      -0.029
vflt          -0.0062      0.001     -4.419      0.000      -0.009      -0.003
runqsz        -1.7235      0.126    -13.644      0.000      -1.971      -1.476
freemem       -0.0005   5.11e-05     -9.186      0.000      -0.001      -0.000
freeswap    9.218e-06    1.9e-07     48.401      0.000    8.84e-06    9.59e-06
==============================================================================
Omnibus:                      980.533   Durbin-Watson:                   2.023
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1932.446
Skew:                          -1.039   Prob(JB):                         0.00
Kurtosis:                       4.941   Cond. No.                     7.14e+06
==============================================================================
```

```
VIF values after dropping 'ppgout':

const       25.484056
lread        5.220098
lwrite       4.229441
scall        2.987783
sread        6.555363
swrite       5.666264
fork        13.188017
exec         3.214984
rchar        2.088006
wchar        1.580437
pgout        6.324897
pgfree       6.097389
atch         1.847637
pgin        14.437958
ppgin       14.617568
pflt        11.703237
vflt        15.362860
runqsz       1.151159
freemem      1.972182
freeswap     1.845464
dtype: float64
```

- VIF values still seem to be high. Hence, dropping other variables one after another as shown below:

  After dropping 'fork':

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                    usr   R-squared:                       0.793
Model:                            OLS   Adj. R-squared:                  0.792
Method:                 Least Squares   F-statistic:                     1214.
Date:                Sun, 05 Mar 2023   Prob (F-statistic):               0.00
Time:                        11:28:42   Log-Likelihood:                -16687.
No. Observations:                5734   AIC:                         3.341e+04
Df Residuals:                    5715   BIC:                         3.354e+04
Df Model:                          18
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         85.0919      0.294    289.002      0.000      84.515      85.669
lread         -0.0636      0.009     -7.188      0.000      -0.081      -0.046
lwrite         0.0462      0.013      3.575      0.000       0.021       0.072
scall         -0.0007   6.28e-05    -11.368      0.000      -0.001      -0.001
sread          0.0026      0.001      2.540      0.011       0.001       0.005
swrite        -0.0066      0.001     -4.629      0.000      -0.009      -0.004
exec          -0.2599      0.049     -5.289      0.000      -0.356      -0.164
rchar      -4.982e-06   4.87e-07    -10.235      0.000   -5.94e-06   -4.03e-06
wchar      -5.221e-06   1.04e-06     -5.022      0.000   -7.26e-06   -3.18e-06
pgout         -0.5468      0.067     -8.154      0.000      -0.678      -0.415
pgfree         0.1126      0.029      3.884      0.000       0.056       0.169
atch           0.5937      0.143      4.150      0.000       0.313       0.874
pgin           0.0533      0.029      1.831      0.067      -0.004       0.110
ppgin         -0.0850      0.020     -4.209      0.000      -0.125      -0.045
pflt          -0.0329      0.002    -18.092      0.000      -0.036      -0.029
vflt          -0.0067      0.001     -5.385      0.000      -0.009      -0.004
runqsz        -1.7225      0.126    -13.637      0.000      -1.970      -1.475
freemem       -0.0005   5.11e-05     -9.196      0.000      -0.001      -0.000
freeswap    9.205e-06   1.89e-07     48.624      0.000    8.83e-06    9.58e-06
==============================================================================
Omnibus:                      981.667   Durbin-Watson:                   2.023
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1940.233
Skew:                          -1.039   Prob(JB):                         0.00
Kurtosis:                       4.949   Cond. No.                     7.07e+06
==============================================================================
```

```
VIF values after dropping 'fork':

const       25.101797
lread        5.215916
lwrite       4.214692
scall        2.929090
sread        6.540038
swrite       5.467054
exec         2.948582
rchar        2.087974
wchar        1.579880
pgout        6.324301
pgfree       6.096861
atch         1.845154
pgin        14.435714
ppgin       14.578592
pflt         9.929178
vflt        11.857791
runqsz       1.150974
freemem      1.971834
freeswap     1.823381
dtype: float64
```

After dropping ‘pgin’:

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                    usr   R-squared:                       0.793
Model:                            OLS   Adj. R-squared:                  0.792
Method:                 Least Squares   F-statistic:                     1285.
Date:                Sun, 05 Mar 2023   Prob (F-statistic):               0.00
Time:                        11:28:43   Log-Likelihood:                -16689.
No. Observations:                5734   AIC:                         3.341e+04
Df Residuals:                    5716   BIC:                         3.353e+04
Df Model:                          17
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         85.1390      0.293    290.213      0.000      84.564      85.714
lread         -0.0641      0.009     -7.241      0.000      -0.081      -0.047
lwrite         0.0466      0.013      3.603      0.000       0.021       0.072
scall         -0.0007   6.28e-05    -11.328      0.000      -0.001      -0.001
sread          0.0026      0.001      2.549      0.011       0.001       0.005
swrite        -0.0067      0.001     -4.649      0.000      -0.009      -0.004
exec          -0.2571      0.049     -5.234      0.000      -0.353      -0.161
rchar       -5.046e-06   4.86e-07   -10.393      0.000      -6e-06   -4.09e-06
wchar       -5.195e-06   1.04e-06    -4.997      0.000   -7.23e-06   -3.16e-06
pgout         -0.5433      0.067     -8.102      0.000      -0.675      -0.412
pgfree         0.1099      0.029      3.797      0.000       0.053       0.167
atch           0.6002      0.143      4.196      0.000       0.320       0.881
ppgin         -0.0502      0.007     -7.276      0.000      -0.064      -0.037
pflt          -0.0331      0.002    -18.270      0.000      -0.037      -0.030
vflt          -0.0064      0.001     -5.229      0.000      -0.009      -0.004
runqsz        -1.7181      0.126    -13.602      0.000      -1.966      -1.471
freemem       -0.0005   5.11e-05     -9.201      0.000      -0.001      -0.000
freeswap     9.179e-06   1.89e-07    48.609      0.000    8.81e-06    9.55e-06
==============================================================================
Omnibus:                      986.106   Durbin-Watson:                   2.022
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1956.098
Skew:                          -1.042   Prob(JB):                         0.00
Kurtosis:                       4.961   Cond. No.                     7.05e+06
==============================================================================
```

```
VIF values after dropping 'pgin':

const       24.910077
lread        5.211756
lwrite       4.213626
scall        2.927634
sread        6.539854
swrite       5.466379
exec         2.945778
rchar        2.076999
wchar        1.579597
pgout        6.319010
pgfree       6.081600
atch         1.844025
ppgin        1.704801
pflt         9.876458
vflt        11.742820
runqsz       1.150570
freemem      1.971808
freeswap     1.813811
dtype: float64
```

After dropping 'vflt':

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                    usr   R-squared:                       0.792
Model:                            OLS   Adj. R-squared:                  0.791
Method:                 Least Squares   F-statistic:                     1357.
Date:                Sun, 05 Mar 2023   Prob (F-statistic):               0.00
Time:                        11:28:43   Log-Likelihood:                -16702.
No. Observations:                5734   AIC:                         3.344e+04
Df Residuals:                    5717   BIC:                         3.355e+04
Df Model:                          16
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         84.9890      0.293    290.429      0.000      84.415      85.563
lread         -0.0674      0.009     -7.623      0.000      -0.085      -0.050
lwrite         0.0496      0.013      3.829      0.000       0.024       0.075
scall         -0.0007    6.3e-05    -11.218      0.000      -0.001      -0.001
sread          0.0023      0.001      2.261      0.024       0.000       0.004
swrite        -0.0074      0.001     -5.206      0.000      -0.010      -0.005
exec          -0.3101      0.048     -6.438      0.000      -0.405      -0.216
rchar      -5.214e-06   4.86e-07    -10.739      0.000   -6.17e-06   -4.26e-06
wchar      -4.386e-06   1.03e-06     -4.256      0.000   -6.41e-06   -2.37e-06
pgout         -0.5322      0.067     -7.923      0.000      -0.664      -0.401
pgfree         0.1030      0.029      3.552      0.000       0.046       0.160
atch           0.5437      0.143      3.803      0.000       0.263       0.824
ppgin         -0.0600      0.007     -8.998      0.000      -0.073      -0.047
pflt          -0.0408      0.001    -38.014      0.000      -0.043      -0.039
runqsz        -1.7107      0.127    -13.514      0.000      -1.959      -1.463
freemem       -0.0005   5.12e-05     -9.356      0.000      -0.001      -0.000
freeswap    9.328e-06   1.87e-07     49.855      0.000    8.96e-06     9.7e-06
==============================================================================
Omnibus:                      921.359   Durbin-Watson:                   2.020
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1791.848
Skew:                          -0.988   Prob(JB):                         0.00
Kurtosis:                       4.895   Cond. No.                     7.02e+06
==============================================================================
```

```
VIF values after dropping 'vflt':

const       24.671813
lread        5.184407
lwrite       4.205451
scall        2.926841
sread        6.520178
swrite       5.407892
exec         2.820231
rchar        2.067881
wchar        1.544589
pgout        6.312670
pgfree       6.068725
atch         1.833481
ppgin        1.581030
pflt         3.441366
runqsz       1.150426
freemem      1.969675
freeswap     1.772518
dtype: float64
```

Similar to these reiterations, I also dropped 'pgfree', 'sread', and 'lwrite'. Finally, the VIF values were low enough (lower than 5) for all variables to finalise the linear regression model, shown as below:

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                    usr   R-squared:                       0.790
Model:                            OLS   Adj. R-squared:                  0.790
Method:                 Least Squares   F-statistic:                     1659.
Date:                Sun, 05 Mar 2023   Prob (F-statistic):               0.00
Time:                        11:28:44   Log-Likelihood:                -16719.
No. Observations:                5734   AIC:                         3.347e+04
Df Residuals:                    5720   BIC:                         3.356e+04
Df Model:                          13
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         85.1098      0.292    291.503      0.000      84.537      85.682
lread         -0.0384      0.004     -8.656      0.000      -0.047      -0.030
scall         -0.0007      6e-05    -11.335      0.000      -0.001      -0.001
swrite        -0.0052      0.001     -4.897      0.000      -0.007      -0.003
exec          -0.3179      0.048     -6.598      0.000      -0.412      -0.223
rchar      -4.734e-06   4.37e-07    -10.825      0.000   -5.59e-06   -3.88e-06
wchar      -4.411e-06   1.03e-06     -4.303      0.000   -6.42e-06    -2.4e-06
pgout         -0.3363      0.038     -8.808      0.000      -0.411      -0.261
atch           0.5511      0.143      3.848      0.000       0.270       0.832
ppgin         -0.0599      0.007     -9.197      0.000      -0.073      -0.047
pflt          -0.0414      0.001    -39.390      0.000      -0.043      -0.039
runqsz        -1.7475      0.127    -13.809      0.000      -1.996      -1.499
freemem       -0.0005   5.12e-05     -9.512      0.000      -0.001      -0.000
freeswap    9.315e-06   1.87e-07     49.901      0.000    8.95e-06    9.68e-06
==============================================================================
Omnibus:                      937.245   Durbin-Watson:                   2.020
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1839.036
Skew:                          -1.000   Prob(JB):                         0.00
Kurtosis:                       4.923   Cond. No.                     6.98e+06
==============================================================================
```

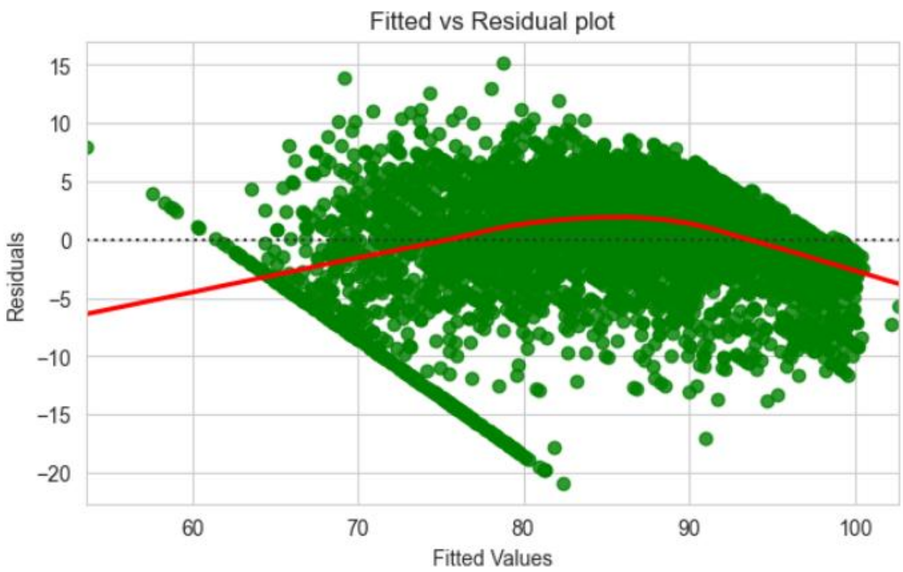
```
VIF values after dropping 'lwrite':

const       24.432718
lread        1.294422
scall        2.640944
swrite       2.939251
exec         2.806984
rchar        1.669087
wchar        1.520686
pgout        2.028511
atch         1.830347
ppgin        1.503077
pflt         3.284418
runqsz       1.143599
freemem      1.955042
freeswap     1.755178
dtype: float64
```

- After dropping the variables that were causing multi-collinearity, we have built the model. Note that it has not lost its R-squared value significantly.
- The former R-squared value was 0.793 and the final value is 0.790, which is a drop of 0.003 (insignificant).
- Therefore, model_25 is the final model.
- Following features are included in the final model: 'const', 'lread', 'scall', 'swrite', 'exec', 'rchar', 'wchar', 'pgout', 'atch', 'ppgin', 'pflt', 'runqsz', 'freemem', 'freeswap'.

ii. The predicted values are generated giving residuals against actual values as shown below:
Note: This is only the first five rows of the data for reference.

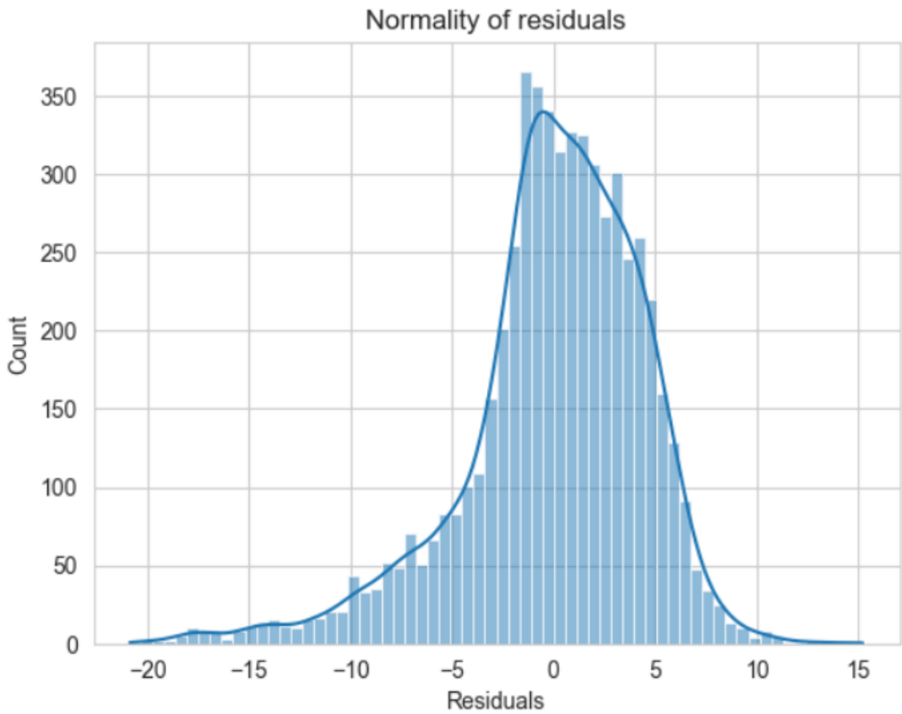
| | Actual Values | Fitted Values | Residuals |
|---|---|---|---|
| **0** | 81.0 | 86.873553 | -5.873553 |
| **1** | 93.0 | 88.050585 | 4.949415 |
| **2** | 64.0 | 64.330359 | -0.330359 |
| **3** | 86.0 | 86.061522 | -0.061522 |
| **4** | 94.0 | 98.473539 | -4.473539 |

iii. Residual plot:



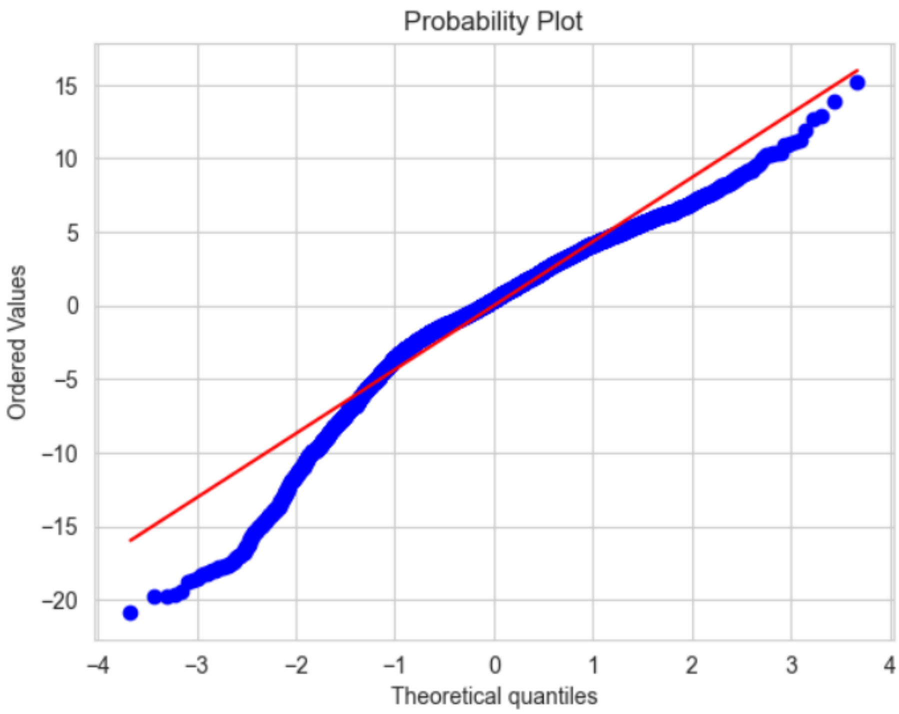
iv. There is some non-linearity spotted in the residual plot. In the attempt to try and correct it, I looked at the pairplot of the dataset to check where the non-linearity might be coming from. 'freemem' seemed to bring in some non-linearity. However, on attempting to adjust it through freemem-squared transformation, the model did not hold good, as the VIF values spiked for multiple variables once again.

v. Checking the normality assumption for residuals:




The distribution looks close to normal and can be accepted.

vi. QQ plot for residuals:



vii. Goldfeld–Quandt test is used to check for homoscedasticity, which is giving the p-value of 0.37, i.e., > 0.05. Hence, the test **fails to reject** the null hypothesis that the residuals are homoscedastic.

viii. All assumptions of linear regression are roughly satisfied.

## 1.4 Inference: Basis on these predictions, what are the business insights and recommendations. Please explain and summarise the various steps performed in this project. There should be proper business interpretation and actionable insights present.

i. Step 1: Created initial model
Step 2: Checked the VIF values for all variables along with the original model's R-squared and adj. R-squared values.
Step 3: Dropped variables with highest VIF value one by one and checked R-squared and adj. R-squared values of the model after dropping each variable.
Step 4: Finally, the model was left with features - const', 'lread', 'scall', 'swrite', 'exec', 'rchar', 'wchar', 'pgout', 'atch', 'ppgin', 'pflt', 'runqsz', 'freemem', 'freeswap', with all the VIF values under 5.
Step 5: The R-squared value of the final model was 0.790 as against 0.793 that we got in the beginning.
Step 6: Created dataframe with actual, predicted and residual values.
Step 7: Checked the linear regression assumptions like linearity, normality, homoscedasticity for the residjuals.

ii. Below is the final equation of linear regression that will help us understand the relationship between 'usr' and independent variables:

usr = 85.0493905502606 + (-0.0383551486247879 56*( lread )) + (-0.0006796180899208*( scall )) + (-0.00516827790480312*( swrite )) + (-0.31791824161693133*( exec )) + (-4.734426806664307e-06*( rchar )) + (-4.410733409483615e-06*( wchar )) + (-0.3362796067741809*( pgout )) + 0.551091802085945*( atch ) + (-0.05990782621159879*( ppgin )) + (-0.04137305160578238*( pflt )) + (-1.7474768971194923*( runqsz )) + (-0.00048675572982739054*( freemem )) + 9.315381320207643e-06*( freeswap )

iii. RMSE for train set = 4.467
RMSE for test set = 4.592

iv. Mean absolute error for train set = 3.333
Mean absolute error for test set = 3.385

v. The RMSE values for both, train and test data are close by, which indicates that the model is stable and not suffering from overfitting.

vi. Business insights from the linear regression equation:
a. 'usr' is majorly dependent on 'runqsz', 'atch', 'pgout', 'exec' when compared to other features. According to this model, we can decrease the time that CPUs run in user mode by making machines depend less on CPU bound processes.
b. If we reduce the number of page attaches (satisfying a page fault by reclaiming a page in memory) per second (atch), we can lower the 'usr'.
c. Reducing the number of page out requests per second (pgout) and number of system exec calls per second (exec) will also have a positive impact on usr.

## Problem 2: Logistic Regression, LDA and CART

You are a statistician at the Republic of Indonesia Ministry of Health and you are provided with a data of 1473 females collected from a Contraceptive Prevalence Survey. The samples are married women who were either not pregnant or do not know if they were at the time of the survey.

The problem is to predict do/don't they use a contraceptive method of choice based on their demographic and socio-economic characteristics.

### 2.1 Data Ingestion: Read the dataset. Do the descriptive statistics and do null value condition check, check for duplicates and outliers and write an inference on it. Perform Univariate and Bivariate Analysis and Multivariate Analysis.

**i.** Head of the data (the first five rows): (first give rows for reference)

| | Wife_age | Wife_ education | Husband_education | No_of_children_born | Wife_religion | Wife_Working | Husband_Occupation | Standard_of_living_index | Media_exp |
|---|---|---|---|---|---|---|---|---|---|
| **0** | 24.0 | Primary | Secondary | 3.0 | Scientology | No | 2 | High | Ex |
| **1** | 45.0 | Uneducated | Secondary | 10.0 | Scientology | No | 3 | Very High | Ex |
| **2** | 43.0 | Primary | Secondary | 7.0 | Scientology | No | 3 | Very High | Ex |
| **3** | 42.0 | Secondary | Primary | 9.0 | Scientology | No | 3 | High | Ex |
| **4** | 36.0 | Secondary | Secondary | 8.0 | Scientology | No | 3 | Low | Ex |

**ii.** The contraceptive dataset has 1473 rows and 10 columns.

**iii.** Null values: ‘Wife_age’ has 71 null values while ‘No_of_children_born’ has 21 null values.

**iv.** 80 duplicates found and dropped from the dataset.

**v.** The info on the original dataset is as follows: 2 *float64* datatype, 1 *int64* datatype, 7 *object* datatype variables.

**vi.** The 5-point-summary (min, 25%, 50%, 75%, max) of each variable is given below through data description:

| | count | unique | top | freq | mean | std | min | 25% | 50% | 75% | max |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wife_age** | 1393.0 | NaN | NaN | NaN | 32.53051 | 8.088188 | 16.0 | 26.0 | 32.0 | 38.0 | 49.0 |
| **Wife_ education** | 1393 | 4 | Tertiary | 515 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| **Husband_education** | 1393 | 4 | Tertiary | 827 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| **No_of_children_born** | 1393.0 | NaN | NaN | NaN | 3.286432 | 2.381791 | 0.0 | 1.0 | 3.0 | 5.0 | 16.0 |
| **Wife_religion** | 1393 | 2 | Scientology | 1186 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| **Wife_Working** | 1393 | 2 | No | 1043 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| **Husband_Occupation** | 1393.0 | 4.0 | 3.0 | 570.0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| **Standard_of_living_index** | 1393 | 4 | Very High | 618 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| **Media_exposure** | 1393 | 2 | Exposed | 1284 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| **Contraceptive_method_used** | 1393 | 2 | Yes | 779 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |

**vii.** The null values in ‘Wife_age’ and ‘No_of_children_born’ have been replaced with median of the respective features.

**viii.** **Univariate Analysis:**

- Value counts of categorical variables are as follows:

```
Value counts for Wife_ education:
Tertiary      515
Secondary     398
Primary       330
Uneducated    150
Name: Wife_ education, dtype: int64


Value counts for Husband_education:
Tertiary      827
Secondary     347
Primary       175
Uneducated     44
Name: Husband_education, dtype: int64


Value counts for Wife_religion:
Scientology        1186
Non-Scientology     207
Name: Wife_religion, dtype: int64


Value counts for Wife_Working:
No     1043
Yes     350
Name: Wife_Working, dtype: int64


Value counts for Husband_Occupation:
3    570
2    415
1    381
4     27
Name: Husband_Occupation, dtype: int64


Value counts for Standard_of_living_index:
Very High    618
High         419
Low          227
Very Low     129
Name: Standard_of_living_index, dtype: int64


Value counts for Media_exposure :
Exposed        1284
Not-Exposed     109
Name: Media_exposure , dtype: int64


Value counts for Contraceptive_method_used:
Yes    779
No     614
Name: Contraceptive_method_used, dtype: int64
```

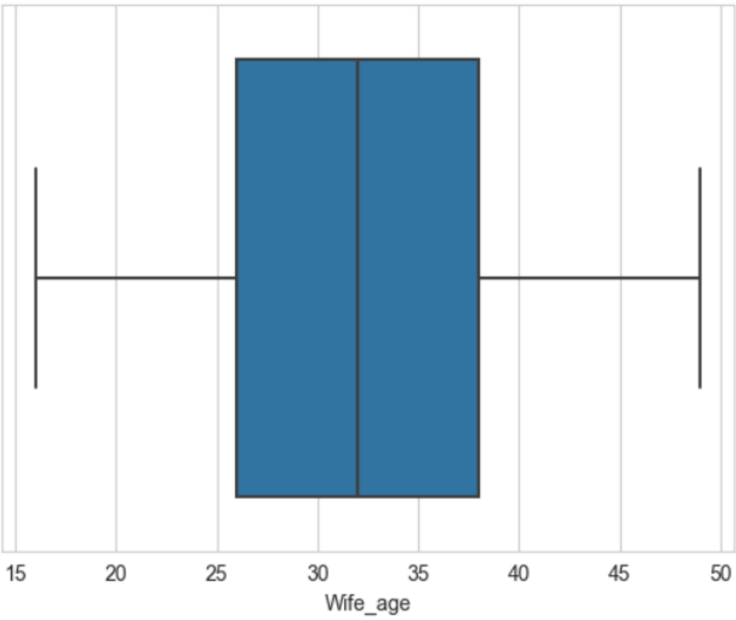
- Value counts for non-categorical, numeric variables:

```
Value counts for Wife_age:
[24. 45. 43. 42. 36. 19. 38. 21. 27. 44. 26. 48. 39. 37. 46. 40. 29. 31.
 33. 25. 28. 47. 32. 49. 34. 20. 22. 30. 23. 35. 41. 17. 18. 16.]
```

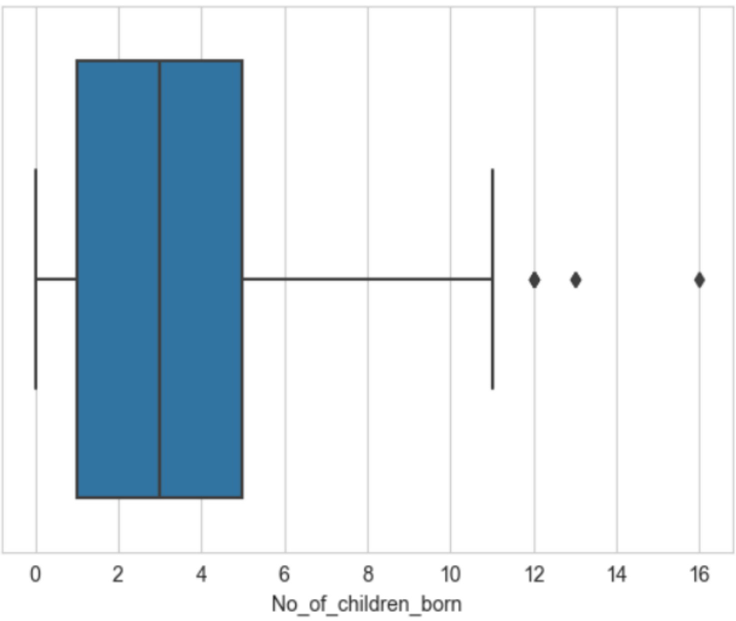
```
Value counts for No_of_children_born:
[ 3. 10.  7.  9.  8.  0.  6.  1.  2.  4.  5. 12. 11. 13. 16.]
```

- Checking outliers for the above continuous and discrete variables, i.e., Wife_age and No_of_children_born:

**Boxplot for Wife_age**



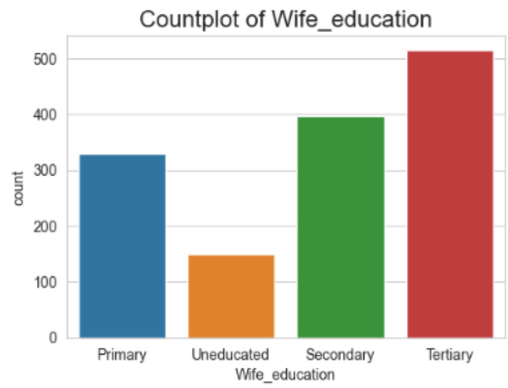

**Boxplot for No_of_children_born**

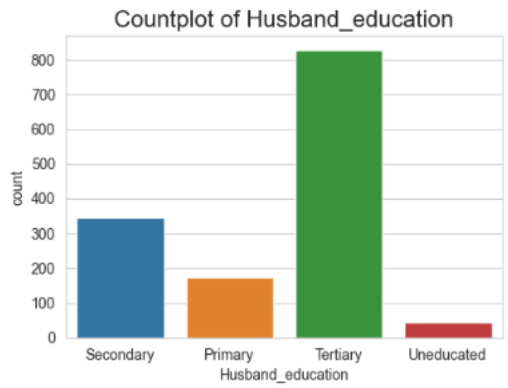


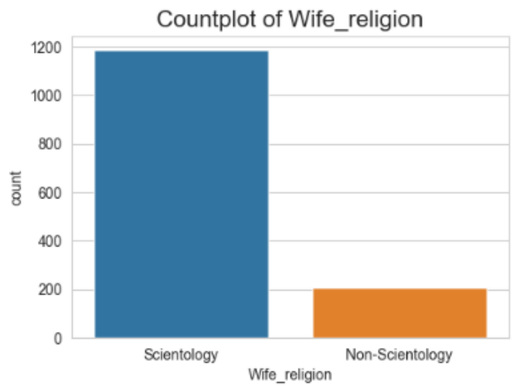

- As shown above, Number_of_children_born has outliers.

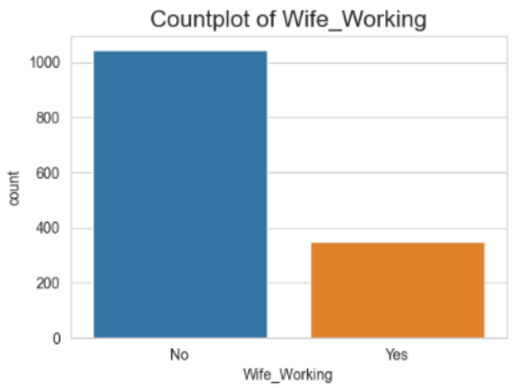
- Treating outliers with the IQR method where the outliers beyond the upper range are replaced with the upper range values using the formula: upper range=Q3+(1.5*IQR).

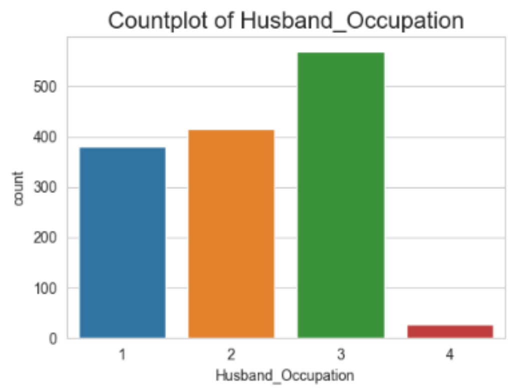
- Countplots for individual features are shown below:

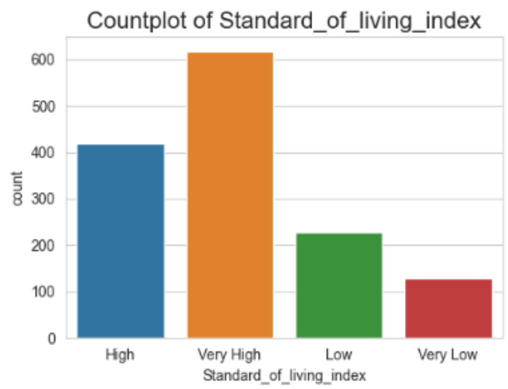


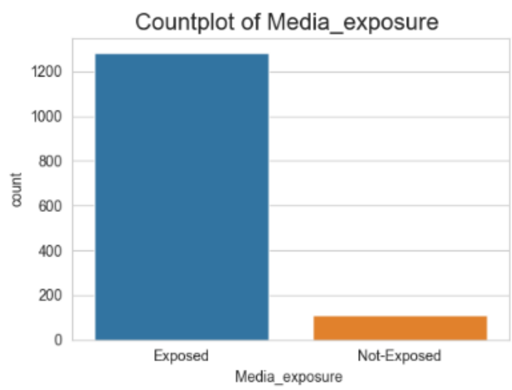



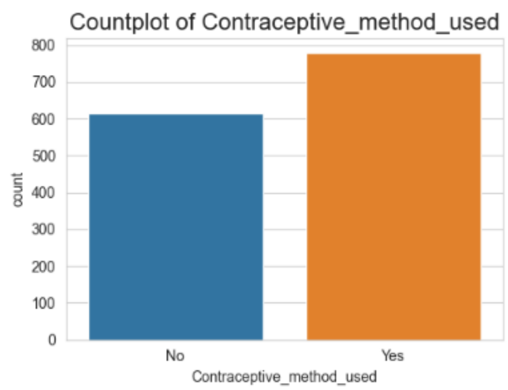



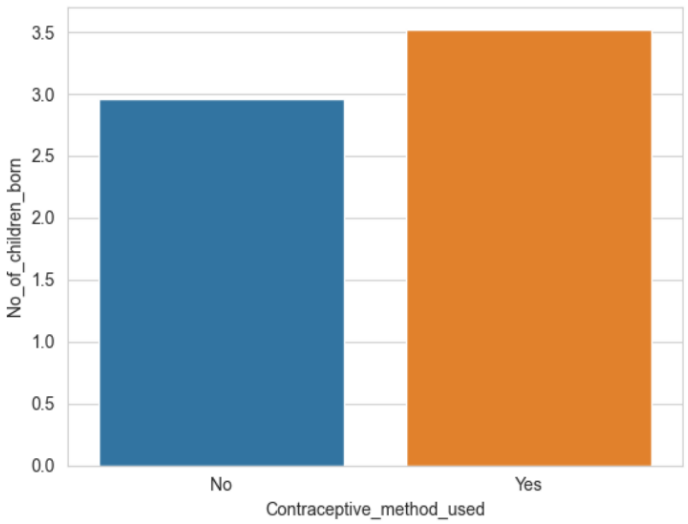



- Insights:
  a. Majority (estimate: 64%) wives are educated at secondary and tertiary levels.
  b. 59% husbands are educated to tertiary level while 24% are educated till secondary level. When compared to wives in tertiary level education, more husbands are in this tier.
  c. According to the above countplots, majority wives are not working belong to scientology religion.
  d. Most husbands are working in tier 3 while almost equal proportion of husbands work in 1 and 2 tiers. The tier 4 of occupation only has about 1.93% of husbands, which is the lowest.
  e. When it comes to standard of living, majority records belong to 'very high' and 'high' categories.
  f. 55.92% of the records use contraceptive while the rest 44% don't use contraceptive.

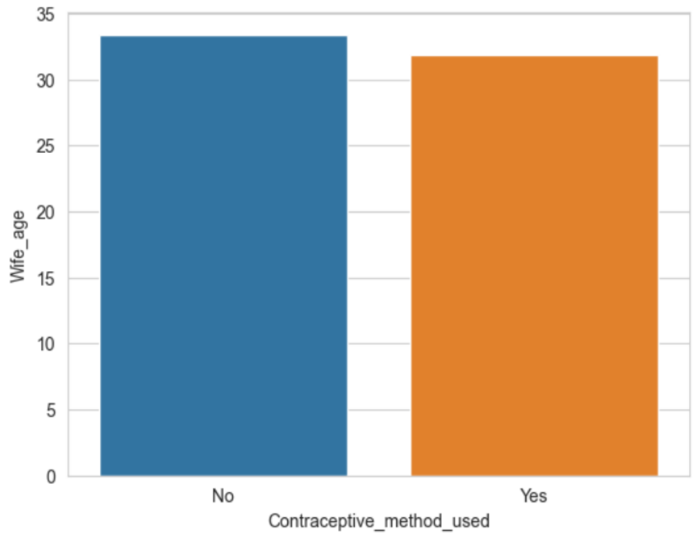
**ix. Bivariate Analysis:**

- When checking the relationship between No_of_children_born with Contraceptive_method_used, we see that there is not a major gap between the two categories of Used and Not Used.

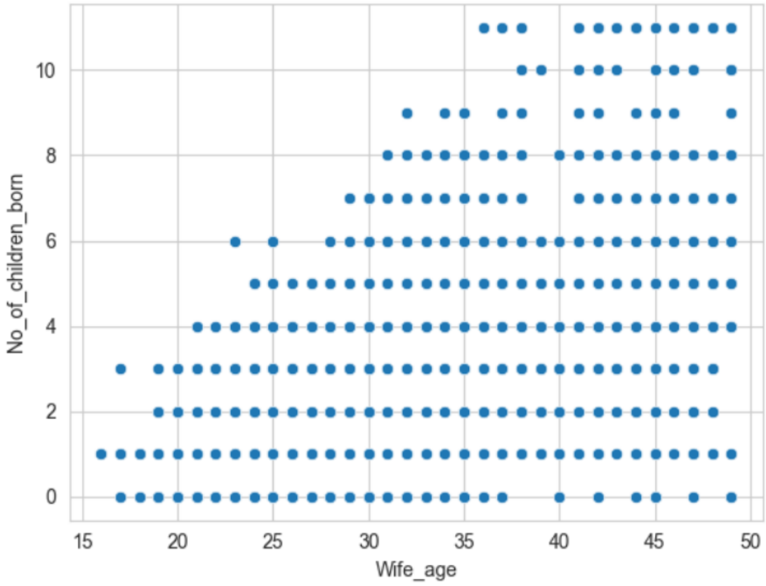



  This could be an indication of ineffective contraceptives used by the records in the dataset.

- When trying to answer the question, “Do more younger women want to use contraceptives for birth control?”, there could not be found any pattern as shown below:

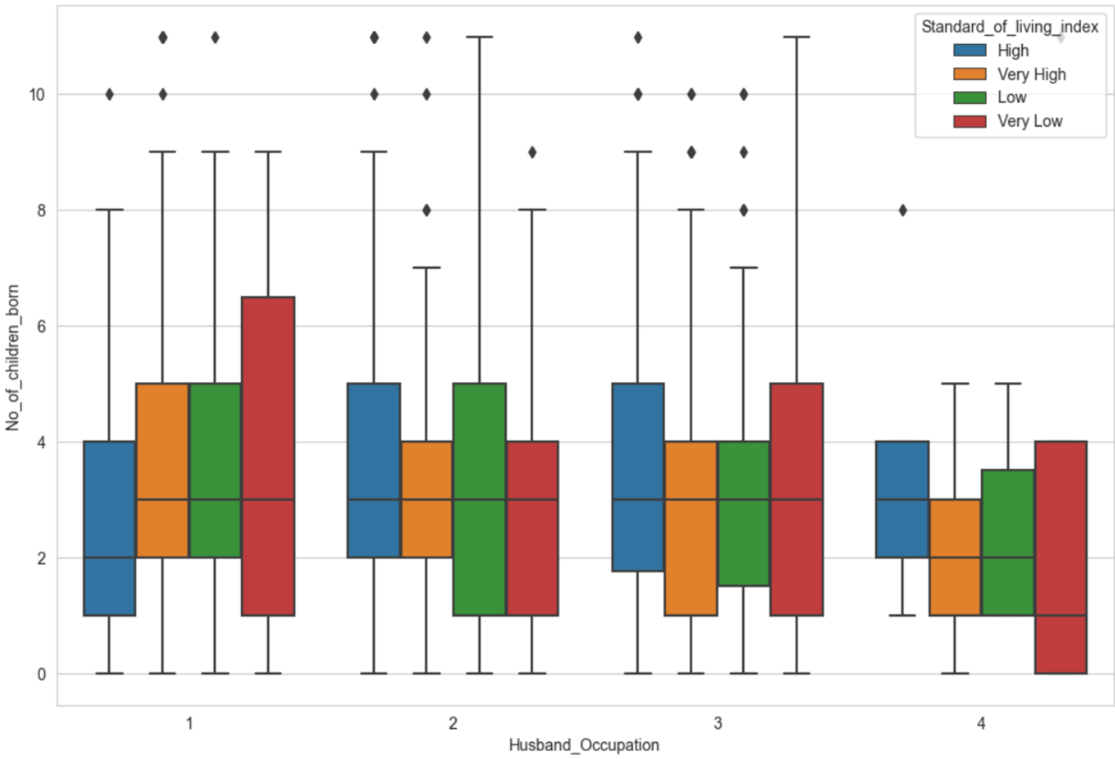


- Moreover, there was only a 0.53 correlation between Wife_age and No_of_children_born. Scatterplot for the two variables is shown below:

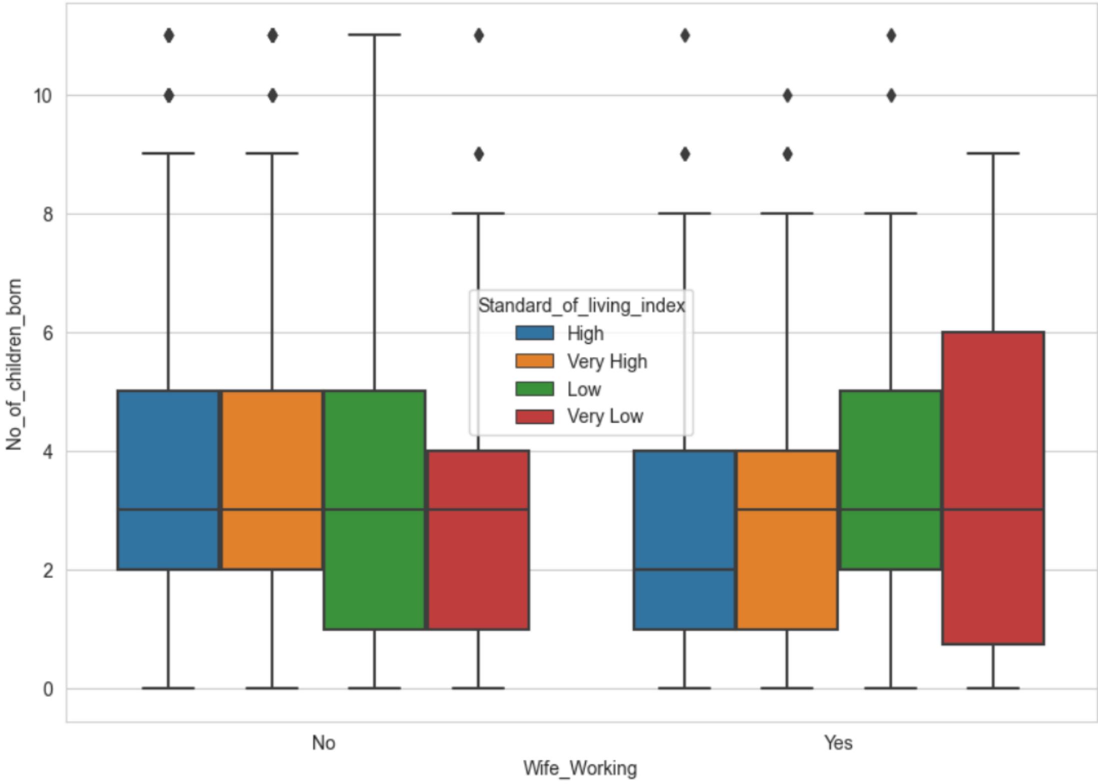



x. **Multivariate Analysis:**

- Number of children born in Husband_Occupation 4 is the lowest.
- Below if the boxplot of No of children born for each Husband_Occupation, with Standard of living as hue:



- In Occupation 2, records with 'Low' Standard of living have the highest number of children whereas in Occupation 3, records with 'Very Low' Standards of living have the highest number of children. This could indicate the inaccessibility of contraceptives and education in these standards of living and Occupation.
- Next, I checked if Wife_Working has an impact on the number of children:




- There was no major difference found in the pattern of Working and Non-working wives with respect to the living standards. However, wives who are not working have higher number of children in all categories of living standards from 'Very High' to 'Very Low'.

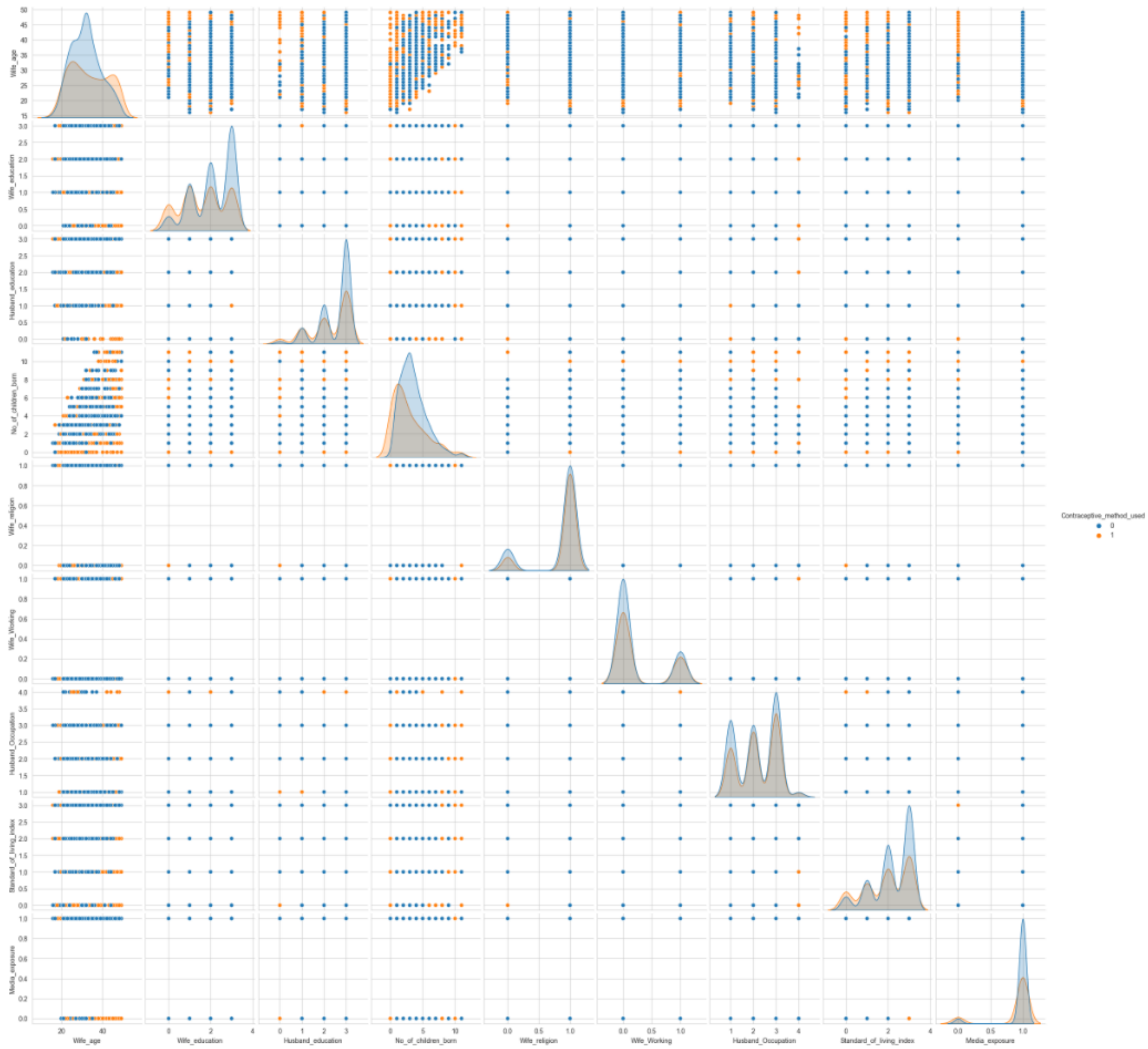
## 2.2 Do not scale the data. Encode the data (having string values) for Modelling. Data Split: Split the data into train and test (70:30). Apply Logistic Regression and LDA (linear discriminant analysis) and CART.

## ***Logistic Regression***

i. To prepare the dataset for modelling, I have converted string values of categorical columns to int values, in an ordinal style.
ii. Criteria used to encode string data: In ordinal categories, 0 indicates the lowest value. For Binary independent variables, 0 indicates 'No' and 1 indicates 'Yes'. For Binary dependent variable, 0 represents 'Yes' and 1 represents 'No', since 'No' class is our class of interest for dependent variable.
iii. All variables converted to numerical values:

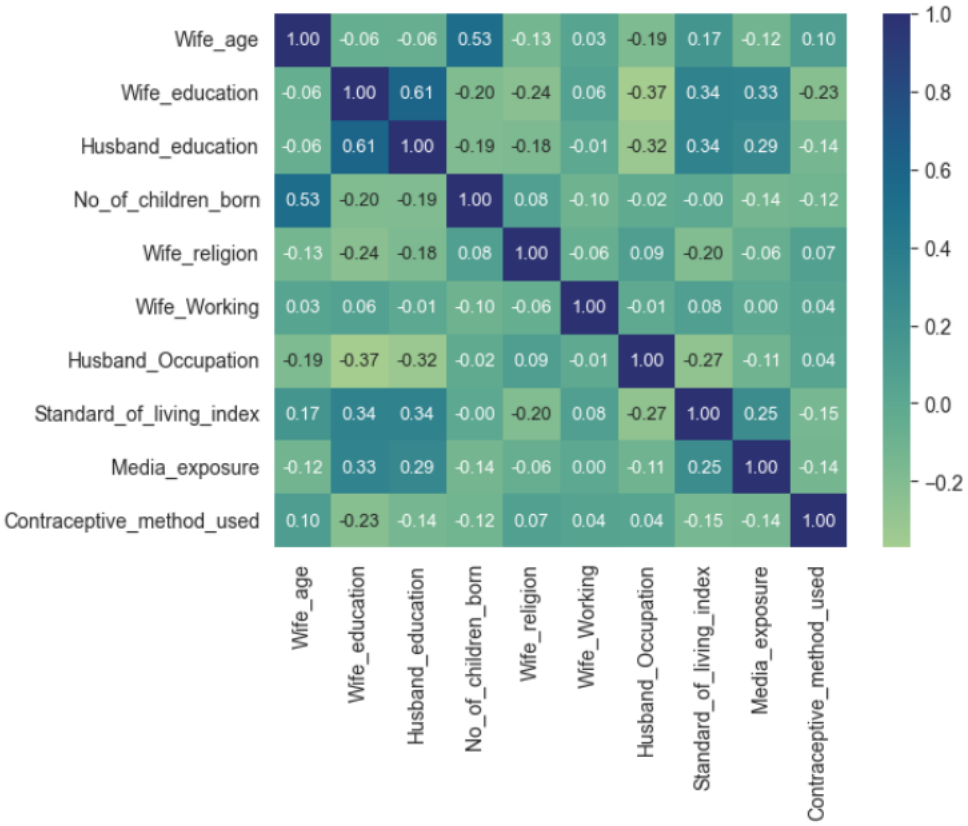
```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 1393 entries, 0 to 1472
Data columns (total 10 columns):
 #   Column                     Non-Null Count  Dtype
---  ------                     --------------  -----
 0   Wife_age                   1393 non-null   float64
 1   Wife_education             1393 non-null   int64
 2   Husband_education          1393 non-null   int64
 3   No_of_children_born        1393 non-null   float64
 4   Wife_religion              1393 non-null   int64
 5   Wife_Working               1393 non-null   int64
 6   Husband_Occupation         1393 non-null   int64
 7   Standard_of_living_index   1393 non-null   int64
 8   Media_exposure             1393 non-null   int64
 9   Contraceptive_method_used  1393 non-null   int64
dtypes: float64(2), int64(8)
memory usage: 152.0 KB
```

iv. Pairplot with class variable ‘Contraceptive_method_used’ as hue:



The diagonals represent the overlap between the independent variables and the class variable. Most of the independent variables overlap between both the classes, which means that they are poor or week predictors and do not split the binary class well.

v. Following is the heatmap indicating correlations amongst variables:




The independent variables do not seem to have multicollinearity. Hence, it is safe to go ahead with building a Logit model.

vi. LOGIT TRAIN DATA SET MODEL:

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| 0 | 0.67 | 0.80 | 0.73 | 547 |
| 1 | 0.66 | 0.50 | 0.57 | 428 |
| accuracy | | | 0.66 | 975 |
| macro avg | 0.66 | 0.65 | 0.65 | 975 |
| weighted avg | 0.66 | 0.66 | 0.66 | 975 |

Accuracy score: 0.6646

LOGIT TEST DATA SET MODEL:

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| 0 | 0.66 | 0.85 | 0.75 | 232 |
| 1 | 0.71 | 0.46 | 0.56 | 186 |
| accuracy | | | 0.68 | 418 |
| macro avg | 0.69 | 0.66 | 0.65 | 418 |
| weighted avg | 0.69 | 0.68 | 0.66 | 418 |

Accuracy score: 0.677

## ***LDA***

i. As mentioned in the question above, not scaling the data for LDA as pre-prcoessing.
ii. Checked independent variables for correlation. All independent variables have low correlation so it is safe to go ahead.
iii. LDA TRAIN DATA SET MODEL:

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| 0 | 0.67 | 0.81 | 0.73 | 547 |
| 1 | 0.66 | 0.48 | 0.56 | 428 |
| accuracy | | | 0.66 | 975 |
| macro avg | 0.66 | 0.64 | 0.64 | 975 |
| weighted avg | 0.66 | 0.66 | 0.65 | 975 |

Accuracy score: 0.6646

LDA TEST DATA SET MODEL:

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| 0 | 0.65 | 0.86 | 0.74 | 232 |
| 1 | 0.71 | 0.42 | 0.53 | 186 |
| accuracy | | | 0.67 | 418 |
| macro avg | 0.68 | 0.64 | 0.63 | 418 |
| weighted avg | 0.68 | 0.67 | 0.65 | 418 |

Accuracy score: 0.665

## ***CART***

i. CART TRAIN DATA SET MODEL:

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| 0 | 0.77 | 0.83 | 0.80 | 547 |
| 1 | 0.76 | 0.68 | 0.72 | 428 |
| accuracy | | | 0.76 | 975 |
| macro avg | 0.76 | 0.75 | 0.76 | 975 |
| weighted avg | 0.76 | 0.76 | 0.76 | 975 |

Accuracy score: 0.7641

CART TEST DATA SET MODEL:

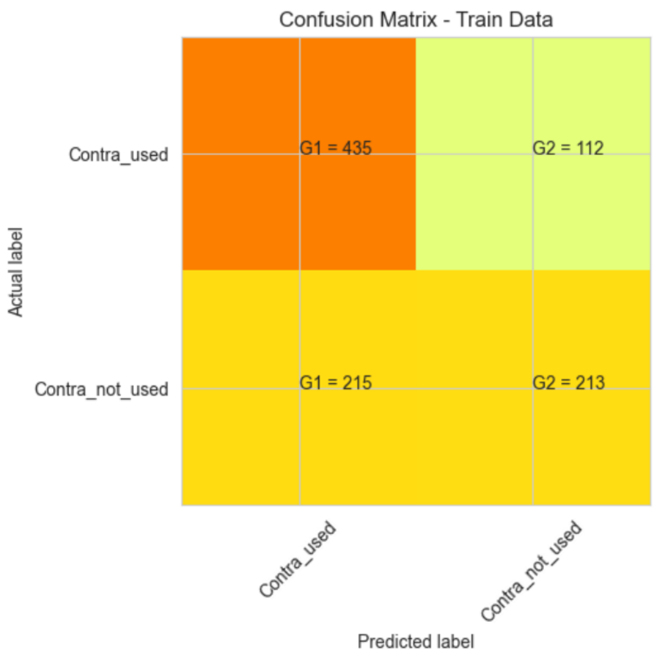
| | precision | recall | f1-score | support |
|---|---|---|---|---|
| 0 | 0.66 | 0.75 | 0.70 | 232 |
| 1 | 0.63 | 0.53 | 0.57 | 186 |
| | | | | |
| accuracy | | | 0.65 | 418 |
| macro avg | 0.65 | 0.64 | 0.64 | 418 |
| weighted avg | 0.65 | 0.65 | 0.65 | 418 |

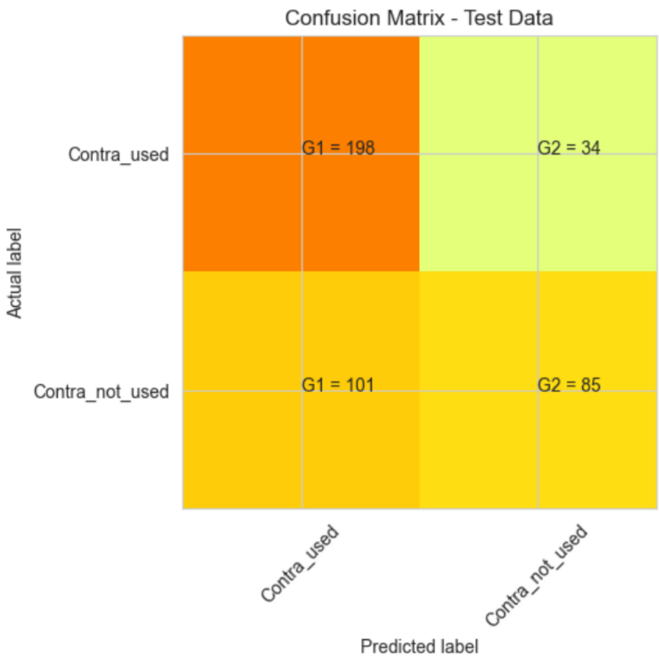
Accuracy score: 0.6507

1. **2.3 Performance Metrics: Check the performance of Predictions on Train and Test sets using Accuracy, Confusion Matrix, Plot ROC curve and get ROC_AUC score for each model Final Model: Compare Both the models and write inference which model is best/optimized.**

## ***Logistic Regression***

i. Confusion matrix:

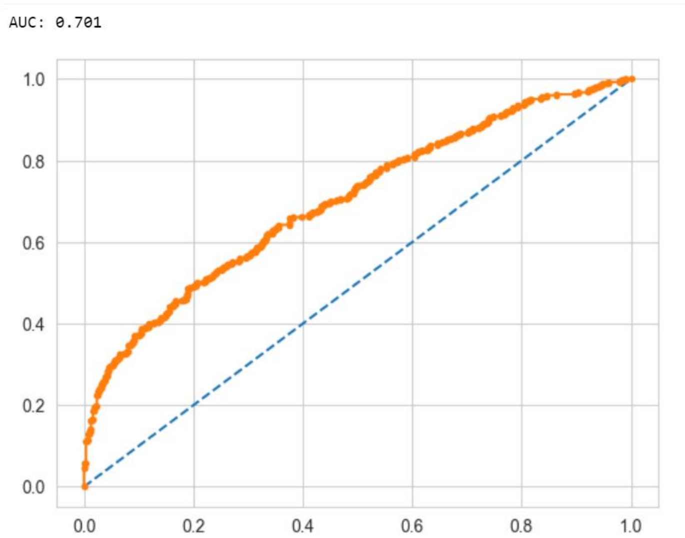




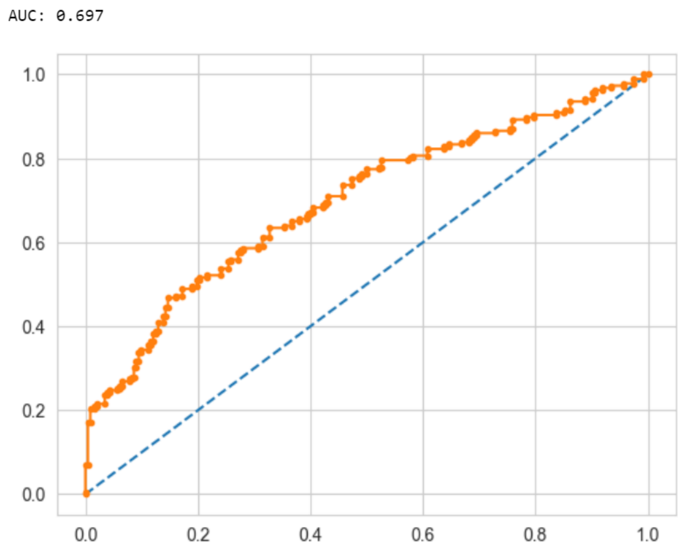

- The logit model has an accuracy score of 0.67 and precision score of 0.71 (for class 1), which is an acceptable score.

vii. In the above confusion matrix:
G1 = 198 is True Positive
G1 = 101 is False Positive
G2 = 85 is True Negative
G2 = 34 is False Negative

viii. ROC curve and AUC score for train set:



ROC curve and AUC score for test set:

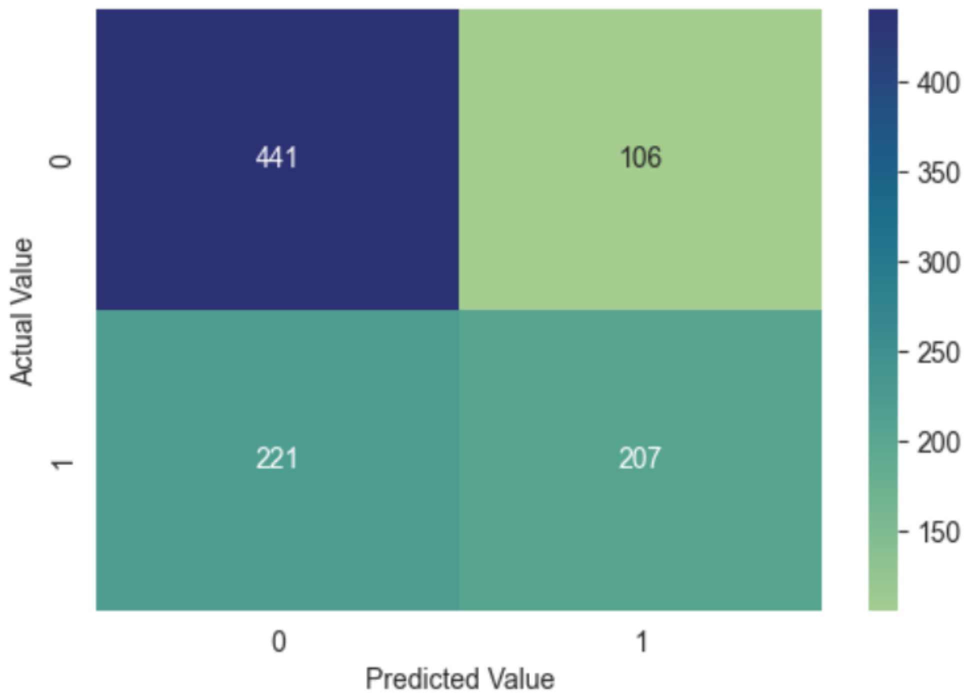



ix. Equation: Y = 0.04305369 + X1*0.07867066, X2*(-0.44697918), X3*(-0.14787693), X4*(-0.27758321), X5*0.39656854, X6*0.16490436, X7*(-0.13464495), X8(-0.19488841), X9*(-0.46818363)

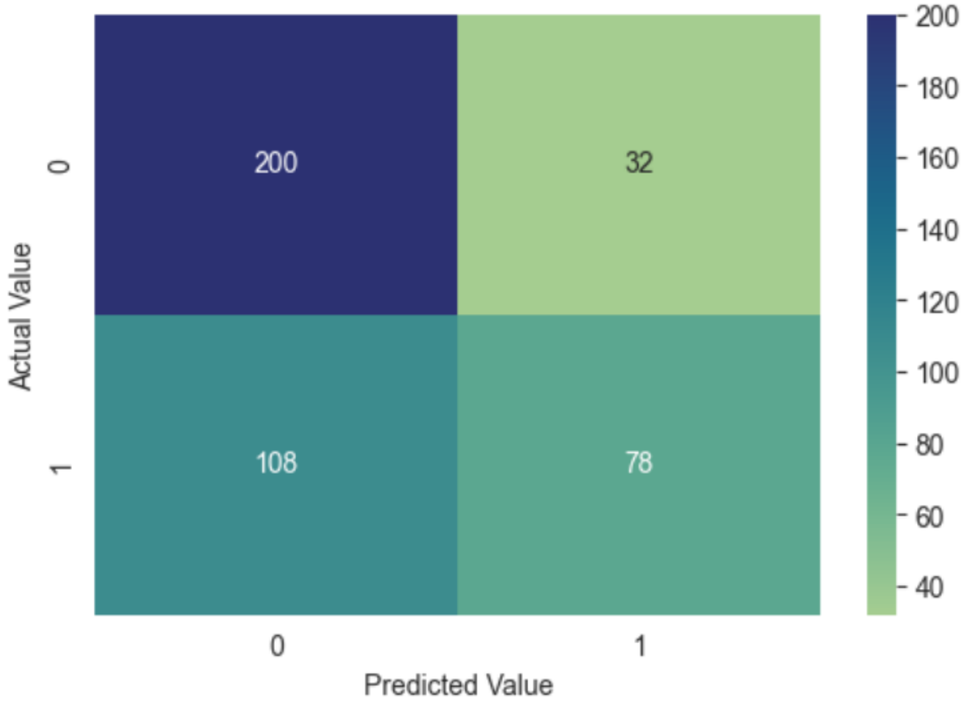
# ***LDA***

iv. Confusion matrix:

TRAIN SET:



TEST SET:




- The LDA model has predicted 110 rows as 1 (target class) and 308 rows as 0.

v. Equation:

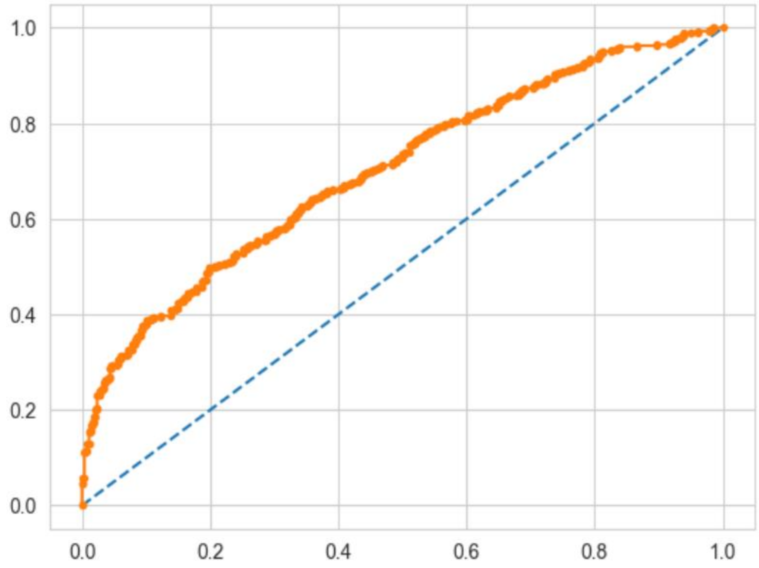
LDF = 0.091 + X1*0.076 + X2*(-0.454) + X3*(-0.141) + X4*(-0.270) + X5*0.406 + X6*(0.169) + X7*(-0.142) + X8*(-0.202) + X9(-0.480)

vi. X9 and X2 have the most discriminating power towards the class variable, since its coefficient has the highest magnitude.

vii. The least discriminating power is coming from X1 since it has the lowest magnitude.

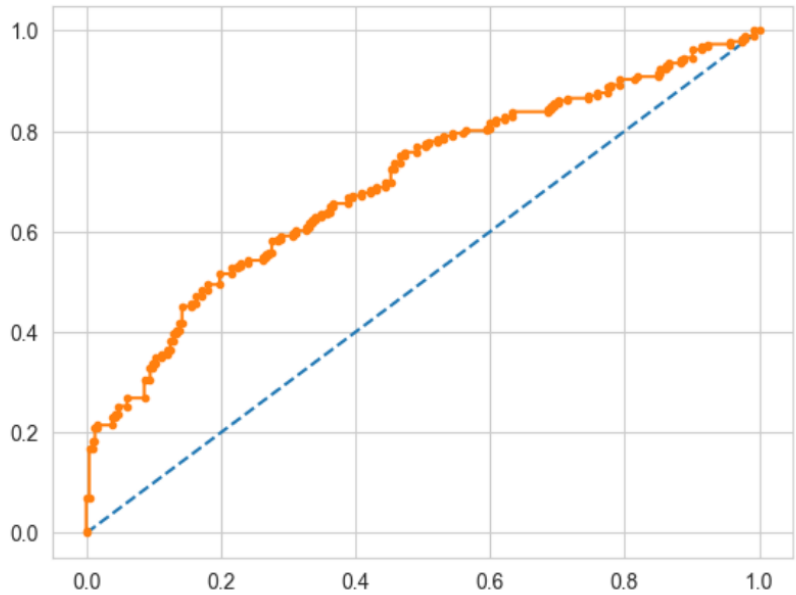
viii. ROC Curve and AUC score for train set:

AUC: 0.701




ROC Curve and AUC score for test set:

AUC: 0.697




## ***<u>CART</u>***

ii. Gini importance of all the features:

| | Gini_Imp |
|---|---|
| Wife_age | 0.302709 |
| Wife_education | 0.103852 |
| Husband_education | 0.076279 |
| No_of_children_born | 0.237810 |
| Wife_religion | 0.040490 |
| Wife_Working | 0.052719 |
| Husband_Occupation | 0.089974 |
| Standard_of_living_index | 0.078466 |
| Media_exposure | 0.017701 |

iii. Above is the Gini importance for each feature. This parameter tells us how much each feature has been used in splitting the dependent variable. The above values are normalized.

iv. After creating the decision tree, pruning was done to regularize the model. The following parameters were used for pruning:

Max depth = 9
Min sample leaf = 10
Min sample split = 30

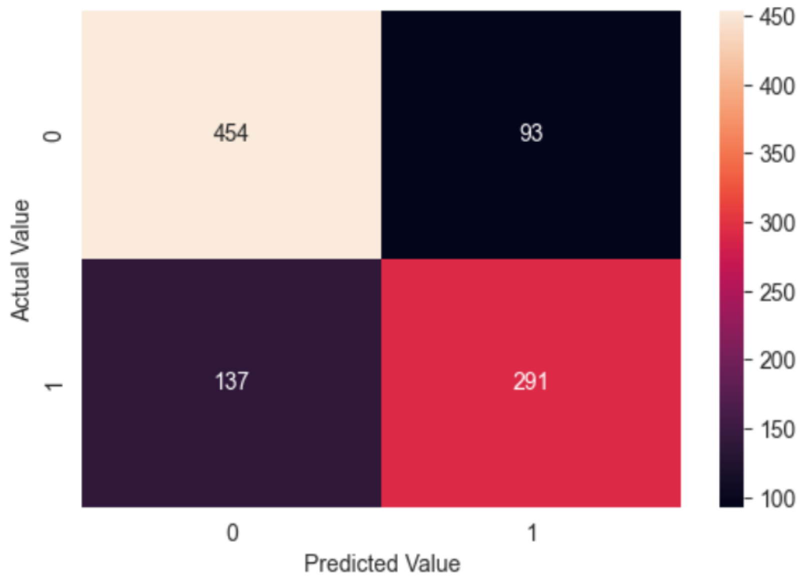
v. New Gini importance table:

| | Gini Imp |
|---|---|
| Wife_age | 0.323388 |
| Wife_education | 0.154638 |
| Husband_education | 0.029856 |
| No_of_children_born | 0.396749 |
| Wife_religion | 0.007844 |
| Wife_Working | 0.002985 |
| Husband_Occupation | 0.039359 |
| Standard_of_living_index | 0.045180 |
| Media_exposure | 0.000000 |

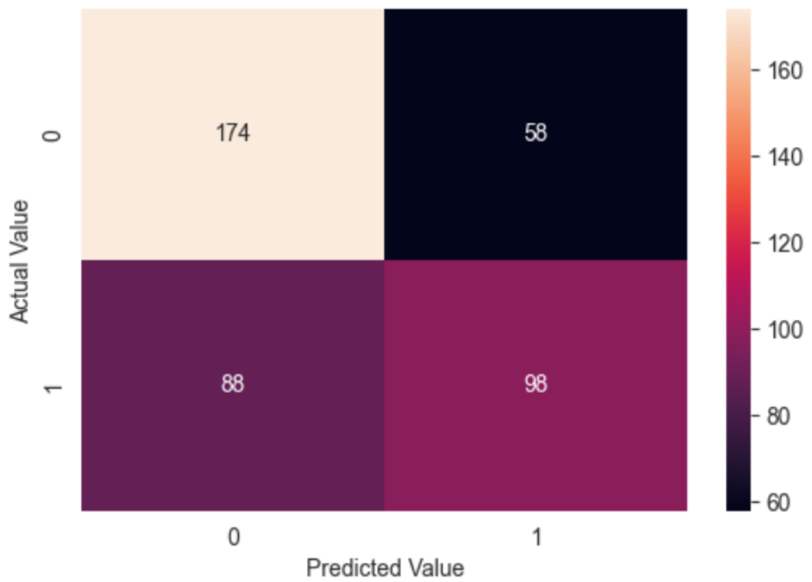
- The feature importance of No_of_children_born, Wife_age, and Wife_education are the highest.
- If the gini importance of any variable is 0, it suggests that this particular variable was not used in splitting the class variable, hence, it can be dropped.
- Above, we can see that Media_exposure feature was not used in classification.
- Wife_working and Wife_religion do not seem to have much effect on 'contraceptive_method_used' as well.

vi. Confusion matrix:

TRAIN DATA:

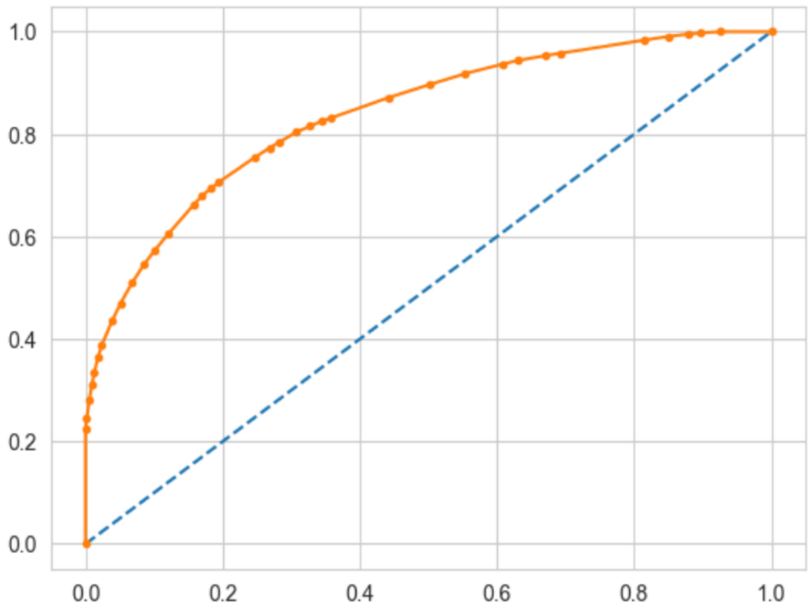



TEST DATA:



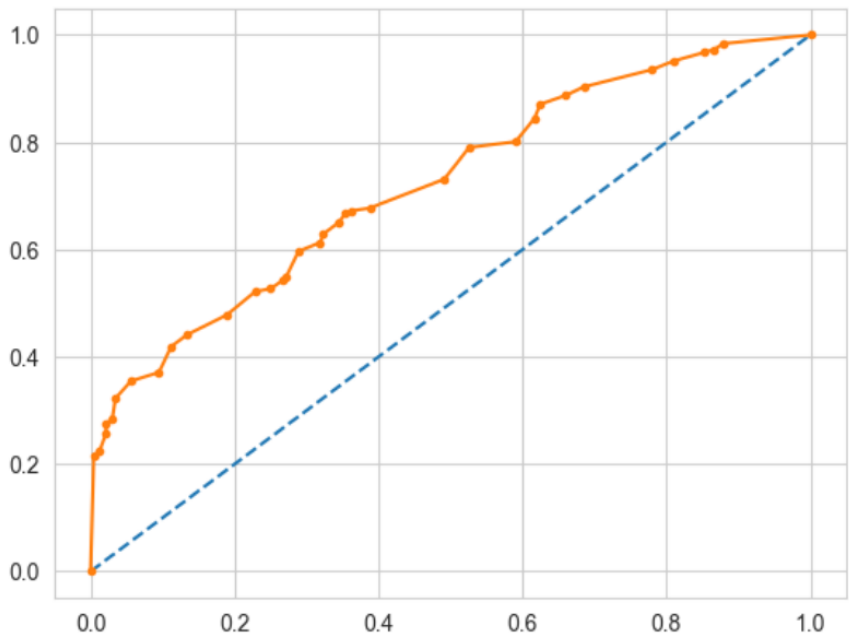

vii. ROC Curve and AUC Score for train set:

AUC: 0.838




ROC Curve and AUC Score for test set:

AUC: 0.722




# ***MODEL COMPARISON AND INSIGHTS:***

i. The model for LOGIT and LDA on training data has the same accuracy score of 0.0.6646. However, LOGIT performed better on test data with the accuracy score of 0.677 against that of CART, i.e., 0.665. One point to be noted is that there was a slight increase the accuracy score of LDA models from train to test set.

ii. The CART train data set accuracy score was 0.764 but dropped to 0.65 for the test data set, which is the biggest drop of all three models.

iii. The test data precision score for class 1 for both LOGIT and LDA is 0.71, while for CART it is 0.63.

iv. The highest AUC score is given by the CART model, i.e., 0.722 (for test data).

v. On a relative scale, the best of the three models is Logistic Regression model.

vi. Logit was able to make 283 correct predictions, LDA made 278 correct predictions, while CART made 272 correct predictions. I would go with the Logistic Regression model to make predictions.

## 2.4 Inference: Basis on these predictions, what are the insights and recommendations. Please explain and summarise the various steps performed in this project. There should be proper business interpretation and actionable insights present.

i. The Logit model gave:
- 198 True Positives
- 101 False Positives
- 85 True Negatives
- 34 is False Negatives

ii. X9, followed by X2 and X3 have the most impact on the dependent variable and hence they have the most power to distinguish between the two classes. X9 and X2 have an inverse effect on Y, while X3 has a direct impact on Y.

iii. Steps involved in building the above models:

a. Step 1: Split the data into X_train, X_test, y_train, y_test.
b. Step 2: Create empty model and fit it into the training set.
c. Step 3: Get model coefficients to check the weight of each variable on the dependent variable.
d. Step 4: Check the intercept of the model.
e. Step 5: Check the AUC score and ROC curve along with the confusion matrix to see how well the discriminating features have predicted the Y variable.