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Data Mining III
CSE 40977

Assignment I

1 - Open CARS1.arff that we saved during Lesson 2. Using the following guidelines, perform additional modeling of the CARS1 data:

(i) using other methods such as SVM, SMO, Decision Stump etc. (choose 4 additional methods)

(ii) Select the top 3 performing methods out of the models we built in the Lesson and the models you built in (i).

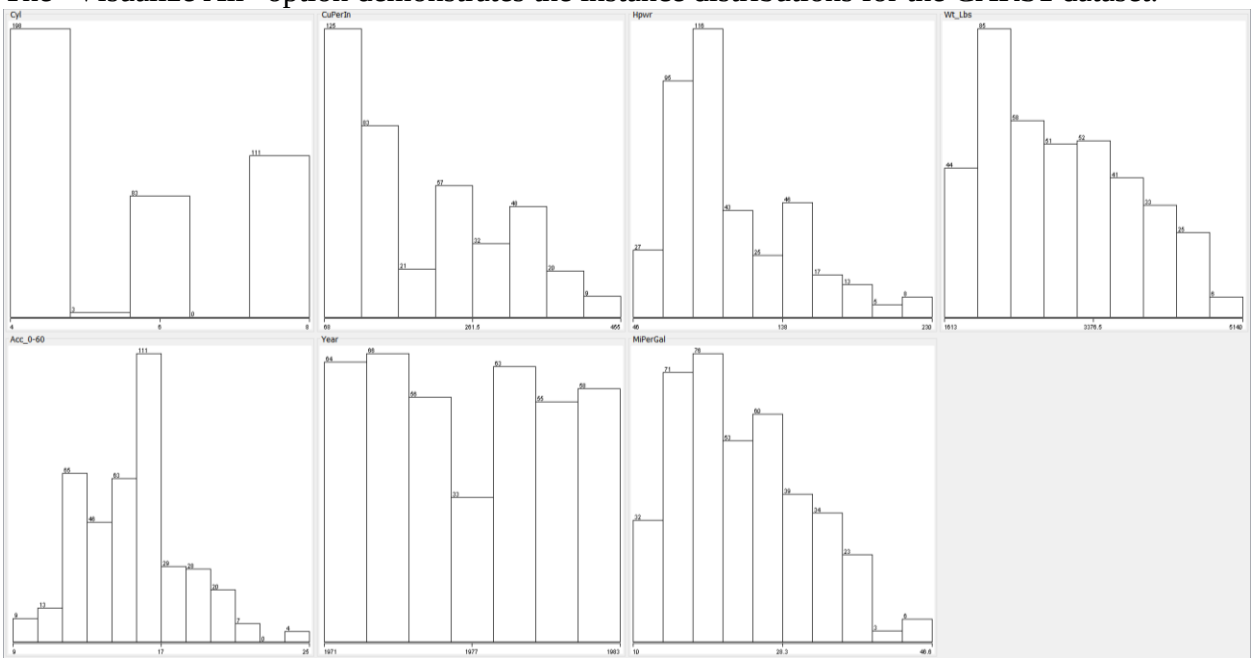
(iii) Build additional models by performing parameter tuning (such as useSmoothed and minNumberInstances in the Model Tree method) on your top three models. Perform 6 runs with the changed parameters and report your best score (for example, two different runs for each of the top three models)..

Workflow

(1). Following Instructions from Lesson 2: Hands-On Case Studies, Step by Step Data Preparation and Modeling of Real-World Data Part I :

The CARS1 dataset was narrowed down from 10 attributes to 3, removing attributes Brand, Model, and Origin from the attribute list when predicting the class attribute, MiPerGal. Furthermore, non-real world values of 3 for Cyl were removed, missing values of MiPerGal were removed, other filtering was completed during pre-processing, and all of the attributes are of type numeric, including the class attribute, MiPerGal.

The “Visualize All” option demonstrates the instance distributions for the CARS1 dataset.



As completed following instructor direction, the M5P or Model Tree classifier was used to create a model to fit the class attribute, MiPerGal. The following model was created with a correlation coefficient of 0.9331 and 10 linear model leaves:

```
=== Run information ===

Scheme:weka.classifiers.trees.M5P -M 4.0
Relation:     CARS1-
weka.filters.unsupervised.attribute.Reorder-
R1,2,3,4,5,6,7,8,10,9-
weka.filters.unsupervised.attribute.MergeTw
oValues-C9-F1-S2-
weka.filters.unsupervised.attribute.MergeTw
oValues-C7-F1-S2-
weka.filters.unsupervised.attribute.MergeTw
oValues-C7-F27-S29-
weka.filters.unsupervised.instance.Remove
WithValues-S0.0-C7-L15,26-H-
weka.filters.unsupervised.attribute.Remove-
R8-
weka.filters.unsupervised.attribute.Remove-
R7-
weka.filters.unsupervised.attribute.Reorder-
R1,2,3,4,5,6,8,7-
weka.filters.unsupervised.attribute.Reorder-
R1,2,3,4,5,6,8,7-
weka.filters.unsupervised.attribute.Remove-
R7
Instances:    397
Attributes:   7
              Cyl
              CuPerIn
              Hpwr
              Wt_Lbs
              Acc_0-60
              Year
              MiPerGal
Test mode:10-fold cross-validation

=== Classifier model (full training set) ===

M5 pruned model tree:
(using smoothed linear models)

CuPerIn <= 190.5 : LM1 (217/40.719%)
CuPerIn >  190.5 :
|   Hpwr <= 141 :
|   |   CuPerIn <= 241 : LM2 (44/17.514%)
|   |   CuPerIn >  241 :
|   |   |   Year <= 1978.5 : LM3 (41/20.043%)
|   |   |   Year >  1978.5 : LM4 (15/28.906%)
|   Hpwr >  141 :
|   |   Wt_Lbs <= 4361.5 :
|   |   |   Year <= 1977.5 :
|   |   |   |   Wt_Lbs <= 3682.5 : LM5
(9/14.809%)
|   |   |   |   Wt_Lbs >  3682.5 : LM6
(31/11.381%)
|   |   |   Year >  1977.5 :
|   |   |   |   Wt_Lbs <= 3997 : LM7
(4/8.682%)
|   |   |   |   Wt_Lbs >  3997 : LM8 (7/4.756%)
|   |   Wt_Lbs >  4361.5 :
|   |   |   Year <= 1974.5 : LM9 (22/8.254%)
|   |   |   Year >  1974.5 : LM10 (7/11.491%)

LM num: 1
MiPerGal =
        -0.0219 * Cyl
        - 0.0438 * CuPerIn
        - 0.0582 * Hpwr
        - 0.0053 * Wt_Lbs
        + 0.911 * Year
        - 1750.8314

LM num: 2
MiPerGal =
        -0.0261 * Cyl
        - 0.0163 * CuPerIn
        - 0.0019 * Hpwr
        - 0.0031 * Wt_Lbs
        + 0.3404 * Year
        - 638.9453

LM num: 3
MiPerGal =
        -0.0261 * Cyl
        - 0.0242 * CuPerIn
```

- 0.01 * Hpwr
- 0.0023 * Wt_Lbs
- 0.2648 * Acc_0-60
+ 0.2856 * Year
- 526.4988

LM num: 4
MiPerGal =
-0.0261 * Cyl
+ 0.011 * CuPerIn
- 0.0169 * Hpwr
- 0.0052 * Wt_Lbs
+ 1.4864 * Year
- 2905.0233

LM num: 5
MiPerGal =
-0.0261 * Cyl
- 0.0017 * CuPerIn
- 0.0143 * Hpwr
- 0.0014 * Wt_Lbs
- 0.0578 * Acc_0-60
+ 0.0007 * Year
+ 22.552

LM num: 6
MiPerGal =
-0.0261 * Cyl
- 0.0009 * CuPerIn
- 0.0056 * Hpwr
- 0.0014 * Wt_Lbs
- 0.0578 * Acc_0-60
+ 0.1733 * Year
- 319.7441

LM num: 7
MiPerGal =
-0.0261 * Cyl
- 0.0056 * Hpwr
- 0.0023 * Wt_Lbs
- 0.0578 * Acc_0-60
+ 0.2464 * Year
- 460.0164

LM num: 8
MiPerGal =
-0.0261 * Cyl
- 0.0056 * Hpwr
- 0.002 * Wt_Lbs
- 0.0578 * Acc_0-60
+ 0.2464 * Year
- 461.4961

LM num: 9
MiPerGal =
-0.0261 * Cyl
- 0.0204 * Hpwr
- 0.0024 * Wt_Lbs
- 0.4546 * Acc_0-60
+ 0.3107 * Year
- 579.9211

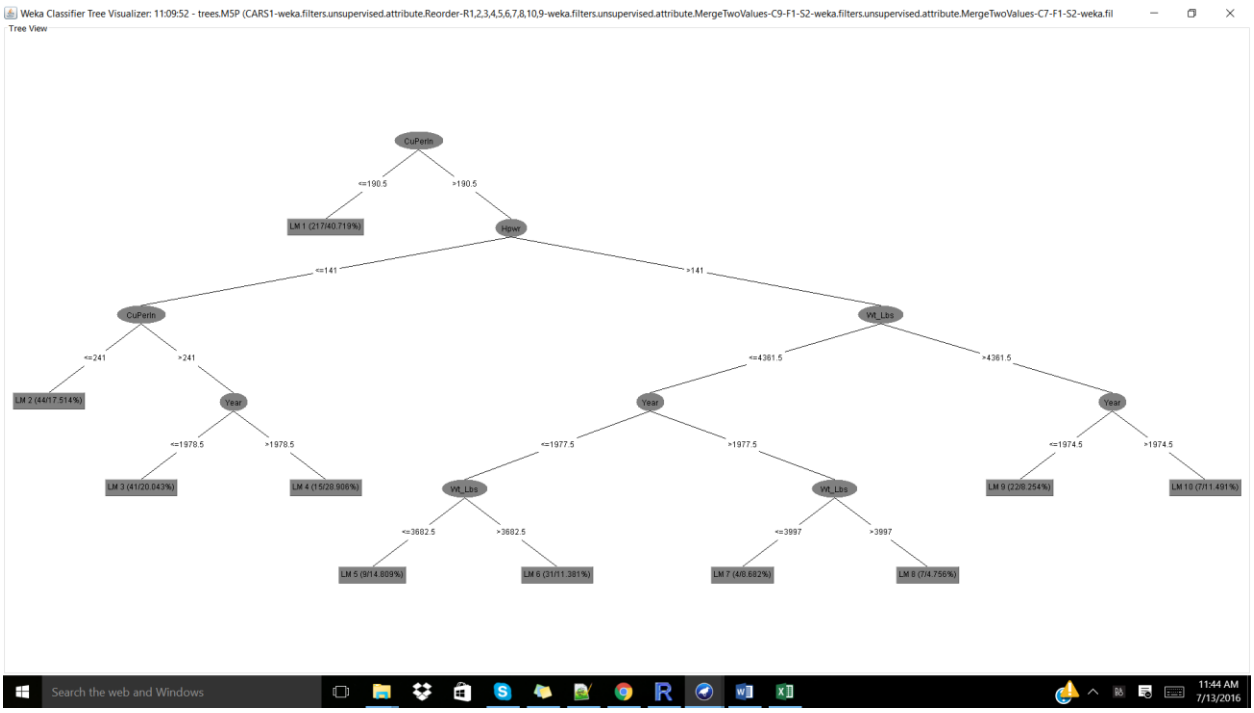
LM num: 10
MiPerGal =
-0.0261 * Cyl
- 0.0041 * Hpwr
- 0.0022 * Wt_Lbs
- 0.2926 * Acc_0-60
+ 0.3885 * Year
- 738.4909

Number of Rules : 10

Time taken to build model: 0.09 seconds

=== Cross-validation ===
=== Summary ===

Correlation coefficient	0.9331
Mean absolute error	2.0088
Root mean squared error	2.801
Relative absolute error	30.5358 %
Root relative squared error	35.8942 %
Total Number of Instances	397



(i)

Furthermore, 4 additional classifiers were implemented on the CARS dataset. Note: all classifiers were run using Cross-validation Folds 10.

Classifier.functions.SMOreg:

=== Run information ===

Scheme:weka.classifiers.functions.SMOreg -C 1.0 -N 0 -I "weka.classifiers.functions.supportVector.RegSMOImproved -L 0.001 -W 1 -P 1.0E-12 -T 0.001 -V" -K "weka.classifiers.functions.supportVector.PolyKernel -C 250007 -E 1.0"
Relation: CARS1-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,7,8,10,9-weka.filters.unsupervised.attribute.MergeTwoValues-C9-F1-S2-weka.filters.unsupervised.attribute.MergeTwoValues-C7-F1-S2-weka.filters.unsupervised.attribute.MergeTwoValues-C7-F27-S29-weka.filters.unsupervised.instance.RemoveWithValues-S0.0-C7-L15,26-H-weka.filters.unsupervised.attribute.Remove-R8-weka.filters.unsupervised.attribute.Remove-R7-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,8,7-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,8,7-weka.filters.unsupervised.attribute.Remove-R7
Instances: 397
Attributes: 7
Cyl
CuPerIn
Hpwr
Wt_Lbs
Acc_0-60
Year
MiPerGal
Test mode:10-fold cross-validation

=== Classifier model (full training set) ===

SMOreg

weights (not support vectors):
- 0.0492 * (normalized) Cyl
- 0.0185 * (normalized) CuPerIn
- 0.0003 * (normalized) Hpwr
- 0.5381 * (normalized) Wt_Lbs
- 0.0793 * (normalized) Acc_0-60
+ 0.191 * (normalized) Year
+ 0.531

Number of kernel evaluations: 79003 (93.383% cached)

Time taken to build model: 0.14 seconds

=== Cross-validation ===
=== Summary ===

Correlation coefficient	0.8962
Mean absolute error	2.5546
Root mean squared error	3.5159
Relative absolute error	38.8325 %
Root relative squared error %	45.0552
Total Number of Instances	397

Classifier.trees.DecisionStump:

=== Run information ===

Scheme:weka.classifiers.trees.DecisionStump
Relation: CARS1-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,7,8,10,9-weka.filters.unsupervised.attribute.MergeTwoValues-C9-F1-S2-weka.filters.unsupervised.attribute.MergeTwoValues-C7-F1-S2-weka.filters.unsupervised.attribute.MergeTwoValues-C7-F27-S29-weka.filters.unsupervised.instance.RemoveWithValues-S0.0-C7-L15,26-H-weka.filters.unsupervised.attribute.Remove-R8-weka.filters.unsupervised.attribute.Remove-R7-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,8,7-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,8,7-weka.filters.unsupervised.attribute.Remove-R7
Instances: 397
Attributes: 7
Cyl
CuPerIn
Hpwr
Wt_Lbs
Acc_0-60
Year
MiPerGal
Test mode:10-fold cross-validation

=== Classifier model (full training set) ===

Decision Stump

Classifications

Cyl <= 5.5 : 29.27661691542288
Cyl > 5.5 : 17.221649484536073
Cyl is missing : 16.5

Time taken to build model: 0.02 seconds

=== Cross-validation ===
=== Summary ===

Correlation coefficient	0.7506
Mean absolute error	3.9553
Root mean squared error	5.1493
Relative absolute error	60.1237 %
Root relative squared error %	65.9872

Total Number of Instances 397

Classifier.functions.MultiLayerPerceptron:

=== Run information ===

Scheme:weka.classifiers.functions.MultilayerPerceptron -L 0.3 -M 0.2 -N 500 -V 0 -S 0 -E 20 -H a
Relation: CARS1-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,7,8,10,9-weka.filters.unsupervised.attribute.MergeTwoValues-C9-F1-S2-weka.filters.unsupervised.attribute.MergeTwoValues-C7-F1-S2-weka.filters.unsupervised.attribute.MergeTwoValues-C7-F27-S29-weka.filters.unsupervised.instance.RemoveWithValues-S0.0-C7-L15,26-H-weka.filters.unsupervised.attribute.Remove-R8-weka.filters.unsupervised.attribute.Remove-R7-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,8,7-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,8,7-weka.filters.unsupervised.attribute.Remove-R7
Instances: 397
Attributes: 7
Cyl
CuPerIn
Hpwr
Wt_Lbs
Acc_0-60
Year
MiPerGal
Test mode:10-fold cross-validation

=== Classifier model (full training set) ===

Linear Node 0
Inputs Weights
Threshold 0.7338230160677247
Node 1 -1.0490847386186852
Node 2 -1.192466466221603
Node 3 -1.0750729557322694
Sigmoid Node 1
Inputs Weights
Threshold -2.3709367417922005
Attrib Cyl 0.5869382221436913
Attrib CuPerIn -0.5338810277776553
Attrib Hpwr 0.6166310499024139
Attrib Wt_Lbs 0.6273561798093562
Attrib Acc_0-60 0.1699677694457307
Attrib Year -0.24636824586124895
Sigmoid Node 2
Inputs Weights
Threshold 3.283637269097142
Attrib Cyl -0.3533600556624747
Attrib CuPerIn 1.3194101137803353
Attrib Hpwr 1.1295008989276456
Attrib Wt_Lbs 2.340340055792048
Attrib Acc_0-60 -0.15073863143399452
Attrib Year -1.3030662697111357
Sigmoid Node 3
Inputs Weights
Threshold -2.3139550911045985
Attrib Cyl 0.33359473083320645
Attrib CuPerIn -0.04362327372448996
Attrib Hpwr 0.1972504595637276
Attrib Wt_Lbs 0.7749845598709538
Attrib Acc_0-60 0.31649992187475295
Attrib Year -0.37375962138858015
Class
Input
Node 0

Time taken to build model: 0.16 seconds

=== Cross-validation ===
=== Summary ===

Correlation coefficient	0.9032
Mean absolute error	2.5442
Root mean squared error	3.3694

Relative absolute error	38.6747 %	Total Number of Instances	397
Root relative squared error %	43.1782		

Classifier.functions.LinearRegression:

=== Run information ===

Scheme:weka.classifiers.functions.LinearRegression -S 0 -R 1.0E-8
Relation: CARS1-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,7,8,10,9-weka.filters.unsupervised.attribute.MergeTwoValues-C9-F1-S2-weka.filters.unsupervised.attribute.MergeTwoValues-C7-F1-S2-weka.filters.unsupervised.attribute.MergeTwoValues-C7-F27-S29-weka.filters.unsupervised.instance.RemoveWithValues-S0.0-C7-L15,26-H-weka.filters.unsupervised.attribute.Remove-R8-weka.filters.unsupervised.attribute.Remove-R7-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,8,7-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,8,7-weka.filters.unsupervised.attribute.Remove-R7
Instances: 397
Attributes: 7
Cyl
CuPerIn
Hpwr
Wt_Lbs
Acc_0-60
Year
MiPerGal
Test mode:10-fold cross-validation

=== Classifier model (full training set) ===

Linear Regression Model

MiPerGal =

-0.3388 * Cyl +
-0.0061 * Wt_Lbs +
0.7251 * Year +
-1389.9404

Time taken to build model: 0 seconds

=== Cross-validation ===
=== Summary ===

Correlation coefficient	0.9009
Mean absolute error	2.5918
Root mean squared error	3.379
Relative absolute error	39.3974 %
Root relative squared error %	43.3016
Total Number of Instances	397

Model Results Matrix:

Model	Correlation Coefficient	Mean Absolute error	Comments
M5P	0.9331	2.0088	Strong classifier
SMOreg	0.8962	2.5546	Weaker classifier
DecisionStump	0.7506	3.9553	Weaker classifier
MultiLayerPerceptron	0.9032	2.5442	Strong classifier
LinearRegression	0.9009	2.5918	Strong classifier

(ii)

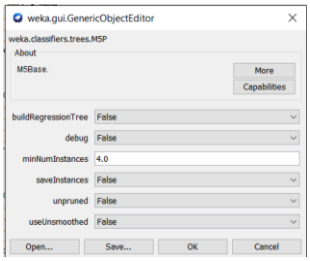
The M5P, MultiLayerPerceptron, and LinearRegression classifier models were found to be strong classifiers (Correlation coefficient > 0.90) and were thus considered for further analysis.

(iii)

Parameter tuning (ie. useSmoothed, minNumberInstances, etc.) was implemented on the top three models:

M5P

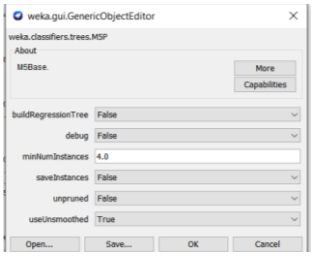
At default



=== Summary ===

Correlation coefficient	0.9331
Mean absolute error	2.0088
Root mean squared error	2.801
Relative absolute error	30.5358 %
Root relative squared error	35.8942 %
Total Number of Instances	397

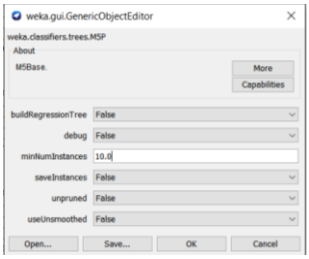
useUnsmoothed: True



=== Summary ===

Correlation coefficient	0.9289
Mean absolute error	2.1014
Root mean squared error	2.8842
Relative absolute error	31.943 %
Root relative squared error	36.9606 %
Total Number of Instances	397

No effect on the correlation coefficient was seen when decreasing the minNumInstances, but the correlation coefficient varied when **minNumInstance = 10.0:**



=== Summary ===

Correlation coefficient	0.9343
Mean absolute error	1.9765
Root mean squared error	2.7765
Relative absolute error	30.0439 %
Root relative squared error	35.5799 %
Total Number of Instances	397

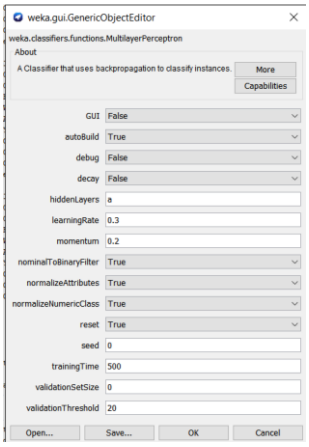
Performance matrix when parameter tuning to M5P classifier

minNumInstances	useUnsmoothed	Correlation coefficient	Mean absolute error
4.0	False	0.9331	2.0088
4.0	True	0.9289	2.1014
10.0	False	0.9343	1.9765

The highest correlation coefficient for the M5P classifier was achieved when minNumInstances = 10.0 and useUnsmoothed was set to False. Although the correlation coefficients were comparable, this M5P classifier had the lowest mean absolute error as well.

MultiLayerPerceptron

At default



=== Summary ===

Correlation coefficient	0.9032
Mean absolute error	2.5442
Root mean squared error	3.3694
Relative absolute error	38.6747 %

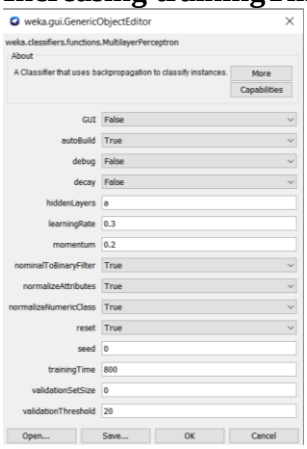
Root relative squared error 43.1782 %
Total Number of Instances 397

Increasing learningRate from 0.3 to 0.5:

=== Summary ===

Correlation coefficient 0.868
Mean absolute error 3.0191
Root mean squared error 3.9587
Relative absolute error 45.8937 %
Root relative squared error 50.7299 %
Total Number of Instances 397

Increasing trainingTime from 500 to 800:



=== Summary ===

Correlation coefficient 0.9023
Mean absolute error 2.5624
Root mean squared error 3.3841
Relative absolute error 38.9507 %
Root relative squared error 43.3665 %
Total Number of Instances 397

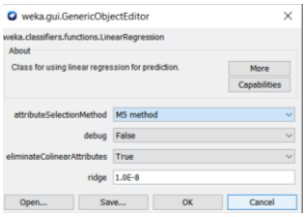
Performance matrix when parameter tuning to MultiLayerPerceptron classifier

learningRate	trainingTime	Correlation coefficient	Mean absolute error
0.3	500	0.9032	2.5442
0.5	500	0.868	3.0191
0.3	800	0.9023	2.5624

Evaluation of the correlation coefficient following learningRate and trainingTime tuning showed that the best MultiLayerPerceptron classifier was achieved using the default settings of learningRate = 0.3 and trainingTime = 500.

LinearRegression

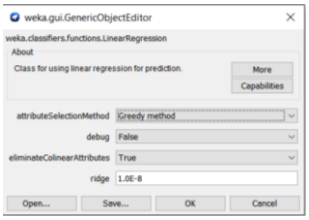
At default



=== Summary ===

Correlation coefficient	0.9009
Mean absolute error	2.5918
Root mean squared error	3.379
Relative absolute error	39.3974 %
Root relative squared error	43.3016 %
Total Number of Instances	397

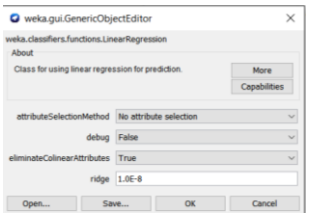
attributeSelectionMethod: Greedy Method



=== Summary ===

Correlation coefficient	0.9009
Mean absolute error	2.5918
Root mean squared error	3.379
Relative absolute error	39.3974 %
Root relative squared error	43.3016 %
Total Number of Instances	397

attributeSelectionMethod: No attribute selection



=== Summary ===

Correlation coefficient	0.8993
Mean absolute error	2.6076
Root mean squared error	3.4056
Relative absolute error	39.6382 %
Root relative squared error	43.6415 %
Total Number of Instances	397

Performance matrix when parameter tuning to LinearRegression classifier

attributeSelectionMethod	Correlation coefficient	Mean absolute error
M5 method	0.9009	2.5918
Greedy method	0.9009	2.5918
No attribute selection	0.8993	2.6076

Varying the attributeSelectionMethod from M5 to Greedy did not affect the performance of the model, thus both modifying the LinearRegression classifier to use M5 or Greedy method selection produces strong models.

Conclusion

Following comparisons of all of the models produced above, the M5P classifier when minNumInstances = 10.0 and useUnsmoothed was set to False was with best classifier with a Correlation coefficient = 0.9343 and a Mean absolute error = 1.9765.

Full Model - M5P: minNumInstances = 10.0 and useUnsmoothed: False

=== Run information ===

Scheme:weka.classifiers.trees.M5P -M 10.0
Relation: CARS1-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,7,8,10,9-weka.filters.unsupervised.attribute.MergeTwoValues-C9-F1-S2-weka.filters.unsupervised.attribute.MergeTwoValues-C7-F1-S2-weka.filters.unsupervised.attribute.MergeTwoValues-C7-F27-S29-weka.filters.unsupervised.instance.RemoveWithValues-S0.0-C7-L15,26-H-weka.filters.unsupervised.attribute.Remove-R8-weka.filters.unsupervised.attribute.Remove-R7-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,8,7-weka.filters.unsupervised.attribute.Reorder-R1,2,3,4,5,6,8,7-weka.filters.unsupervised.attribute.Remove-R7
Instances: 397
Attributes: 7
Cyl
CuPerIn

Hpwr
Wt_Lbs
Acc_0-60
Year
MiPerGal

Test mode:10-fold cross-validation

=== Classifier model (full training set) ===

M5 pruned model tree:
(using smoothed linear models)

CuPerIn <= 190.5 : LM1 (217/40.719%)
CuPerIn > 190.5 : LM2 (180/26.89%)

LM num: 1
MiPerGal =
-0.0438 * CuPerIn
- 0.0582 * Hpwr
- 0.0054 * Wt_Lbs
+ 0.9119 * Year
- 1752.8

LM num: 2
MiPerGal =
-0.0149 * Hpwr
- 0.0034 * Wt_Lbs
+ 0.4218 * Year
- 801.8689

Number of Rules : 2

Time taken to build model: 4.69 seconds

=== Cross-validation ===
=== Summary ===

Correlation coefficient	0.9343
Mean absolute error	1.9765
Root mean squared error	2.7765
Relative absolute error	30.0439 %
Root relative squared error	35.5799 %
Total Number of Instances	397