



BIRZEIT UNIVERSITY

**Faculty of Engineering and Technology
Electrical and Computer Engineering Department**

**Artificial Intelligence
ENCS3340**

**Project #2
Machine Learning for Classification**

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Section: 2
Date: 20/6/2024

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Introduction

Objective: The objective of this project is to evaluate and compare various machine learning algorithms for a classification task using WEKA. The chosen models for this analysis are Decision Tree (J48), Naïve Bayes, and Multilayer Perceptron (MLP).

1. Dataset Description

My student ID ends in 8. Since $8 \bmod 3$ equals 2, we'll use the Raisin Dataset.

Dataset: Raisin Dataset

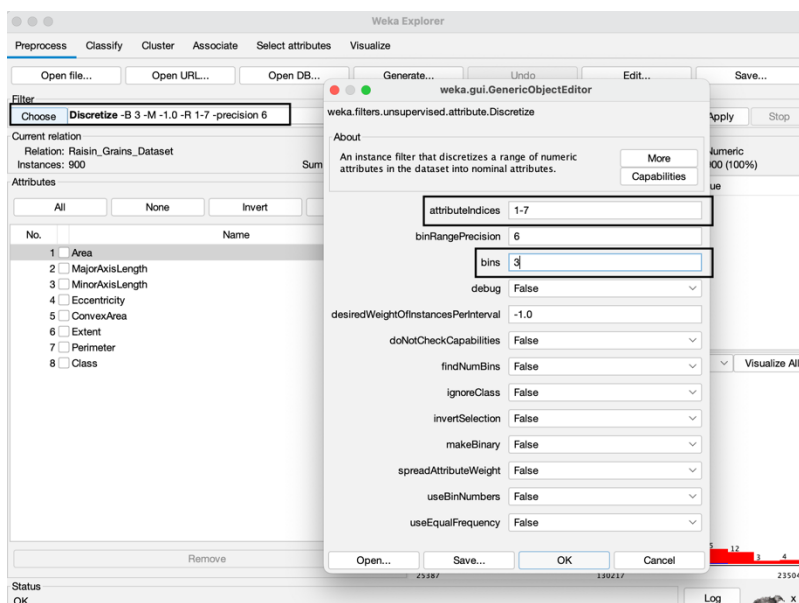
Attributes:

1. Area
2. Perimeter
3. MajorAxisLength
4. MinorAxisLength
5. Eccentricity
6. ConvexArea
7. Extent
8. Class

2. Data Preparation

Discretization of continuous attributes:

To prepare the dataset for machine learning models, we transformed continuous attributes into nominal ones by discretizing them. Attributes such as Area, Perimeter, MajorAxisLength, MinorAxisLength, Eccentricity, ConvexArea, and Extent were each divided into 3 bins or categories. This process converted values like the Area into distinct groups such as "small", "medium", and "large". Using the Discretize filter in WEKA, we simplified the data, making it easier to analyze.



AttributeIndices: 1-7

Indicates that the first seven attributes (Area, MajorAxisLength, MinorAxisLength, Eccentricity, ConvexArea, Extent, and Perimeter) will be discretized.

bins: 3

The number of bins or categories into which each attribute will be divided. Each continuous attribute will be converted into three nominal.

3. Experiments and Results

3.1 Decision Tree (J48)

3.1.1 Initial Settings

confidenceFactor: This parameter controls the pruning process. A lower value results in more pruning, while a higher value results in less pruning. The default value is 0.25.

minNumObj: This parameter sets the minimum number of instances per leaf. The default value is 2, meaning each leaf must have at least 2 instances.

The screenshot shows the Weka Explorer interface with the J48 classifier selected. The 'Test options' tab is active, showing 'Cross-validation' with 'Folds' set to 5 and 'Percentage split' at 66%. The 'Classifier output' tab displays the tree structure and performance metrics. The 'Summary' section shows a stratified cross-validation result with 728 correctly classified instances and 172 incorrectly classified instances, achieving an 80.8889% accuracy. The 'Detailed Accuracy By Class' table shows performance for both 'Kecimen' and 'Besni' classes. The 'Confusion Matrix' is also displayed.

| | TP Rate | FP Rate | Precision | Recall | F-Measure | MCC | ROC Area | PRC Area | Class |
|---------------|---------|---------|-----------|--------|-----------|-------|----------|----------|-------|
| Weighted Avg. | 0.809 | 0.191 | 0.843 | 0.809 | 0.804 | 0.651 | 0.798 | 0.774 | Besni |

3.1.2 Increase confidenceFactor

Increasing the confidenceFactor to 0.9 reduces pruning aggressiveness, capturing more training data details but risking overfitting. This might improve training accuracy and metrics but may not generalize well to new data.

The screenshot shows the Weka Explorer interface with the J48 classifier selected. The 'Test options' tab is active, showing 'Cross-validation' with 'Folds' set to 5 and 'Percentage split' at 66%. The 'Classifier output' tab displays the tree structure and performance metrics. The 'Summary' section shows a stratified cross-validation result with 725 correctly classified instances and 175 incorrectly classified instances, achieving an 80.5556% accuracy. The 'Detailed Accuracy By Class' table shows performance for both 'Kecimen' and 'Besni' classes. The 'Confusion Matrix' is also displayed.

| | TP Rate | FP Rate | Precision | Recall | F-Measure | MCC | ROC Area | PRC Area | Class |
|---------------|---------|---------|-----------|--------|-----------|-------|----------|----------|-------|
| Weighted Avg. | 0.806 | 0.194 | 0.834 | 0.806 | 0.801 | 0.639 | 0.841 | 0.818 | Besni |

3.1.3 Decrease confidenceFactor

Decreasing the confidenceFactor makes the pruning process more aggressive, leading the model to prune more branches and potentially reduce overfitting by creating a simpler tree structure.

Impact: The adjusted setting caused a slight rise in accuracy from 80.89% to 82.22%, indicating that the tree became more generalized and better at accurately classifying unseen instances.

The screenshot shows the Weka Explorer interface with the J48 classifier selected. The 'Test options' tab is active, showing 'Cross-validation' with 'Folds' set to 5. The 'Classifier output' tab displays the following results:

Area = '(95273.666667-165168.333333)': Besni (61.0/12.0)
Area = '(165168.333333-inf)': Keciemen (0.0)
MajorAxisLength = '(482.850341-740.071141)': Besni (237.0/2.0)
MajorAxisLength = '(740.071141-inf)': Besni (10.0/1.0)

Number of Leaves : 7
Size of the tree : 10
Time taken to build model: 0 seconds

==== Stratified cross-validation ====

==== Summary ====

| | Correctly Classified Instances | 728 | 80.889 % |
|----------------------------------|--------------------------------|----------|----------|
| Incorrectly Classified Instances | 172 | 19.111 % | |
| Kappa statistic | 0.6178 | | |
| Mean absolute error | 0.2842 | | |
| Root mean squared error | 0.3781 | | |
| Relative absolute error | 56.8387 % | | |
| Root relative squared error | 75.6294 % | | |
| Total Number of Instances | 900 | | |

==== Detailed Accuracy By Class ====

| | TP Rate | FP Rate | Precision | Recall | F-Measure | MCC | ROC Area | PRC Area | Class |
|---------------|---------|---------|-----------|--------|-----------|-------|----------|----------|----------|
| | 0.967 | 0.349 | 0.735 | 0.967 | 0.835 | 0.651 | 0.798 | 0.711 | Keciemen |
| | 0.651 | 0.833 | 0.951 | 0.651 | 0.773 | 0.651 | 0.798 | 0.837 | Besni |
| Weighted Avg. | 0.809 | 0.191 | 0.843 | 0.809 | 0.804 | 0.651 | 0.798 | 0.774 | |

==== Confusion Matrix ====

| | a | b | ← classified as |
|---------|---|---|-----------------|
| 435 15 | | | a = Keciemen |
| 157 293 | | | b = Besni |

The GenericObjectEditor window shows the 'confidenceFactor' parameter set to 0.1.

3.1.4 Increase minNumObj

Setting minNumObj to 5 ensures that each leaf contains at least 5 instances, preventing the formation of overly specific leaves and reducing overfitting.

The improvements in precision, recall, and F1-score indicate that the model's predictions are more reliable and balanced. Additionally, the increase in accuracy demonstrates better generalization capability.

The screenshot shows the Weka Explorer interface with the J48 classifier selected. The 'Test options' tab is active, showing 'Cross-validation' with 'Folds' set to 5. The 'Classifier output' tab displays the following results:

Area = '(95273.666667-165168.333333)': Besni (61.0/12.0)
Area = '(165168.333333-inf)': Keciemen (0.0)
MajorAxisLength = '(482.850341-740.071141)': Besni (237.0/2.0)
MajorAxisLength = '(740.071141-inf)': Besni (10.0/1.0)

Number of Leaves : 5
Size of the tree : 7
Time taken to build model: 0 seconds

==== Stratified cross-validation ====

==== Summary ====

| | Correctly Classified Instances | 728 | 80.889 % |
|----------------------------------|--------------------------------|----------|----------|
| Incorrectly Classified Instances | 172 | 19.111 % | |
| Kappa statistic | 0.6178 | | |
| Mean absolute error | 0.2842 | | |
| Root mean squared error | 0.3782 | | |
| Relative absolute error | 56.9597 % | | |
| Root relative squared error | 75.6476 % | | |
| Total Number of Instances | 900 | | |

==== Detailed Accuracy By Class ====

| | TP Rate | FP Rate | Precision | Recall | F-Measure | MCC | ROC Area | PRC Area | Class |
|---------------|---------|---------|-----------|--------|-----------|-------|----------|----------|----------|
| | 0.967 | 0.349 | 0.735 | 0.967 | 0.835 | 0.651 | 0.798 | 0.711 | Keciemen |
| | 0.651 | 0.833 | 0.951 | 0.651 | 0.773 | 0.651 | 0.798 | 0.837 | Besni |
| Weighted Avg. | 0.809 | 0.191 | 0.843 | 0.809 | 0.804 | 0.651 | 0.798 | 0.774 | |

==== Confusion Matrix ====

| | a | b | ← classified as |
|---------|---|---|-----------------|
| 435 15 | | | a = Keciemen |
| 157 293 | | | b = Besni |

The GenericObjectEditor window shows the 'minNumObj' parameter set to 5.

3.2 Naïve Bayes

3.2.1 Initial settings

The screenshot shows the Weka Explorer interface with the Naive Bayes classifier selected. The 'Test options' section shows 'Cross-validation' with 'Folds' set to 5. The 'Result list' on the left shows several files, with '01:19:40 - bayes.NaiveBayes' selected. The 'Classifier output' section displays the following data:

| Perimeter | | |
|----------------------|-------|-------|
| '(-inf,-1311.967]' | 448.0 | 232.0 |
| '(1311.967-2004.86]' | 2.0 | 216.0 |
| '(2004.86-inf)' | 3.0 | 5.0 |
| [total] | 453.0 | 453.0 |

The 'Time taken to build model' is 0 seconds. The 'Summary' section shows:

| Correctly Classified Instances | 730 | 81.1111 % |
|----------------------------------|-----------|-----------|
| Incorrectly Classified Instances | 170 | 18.8889 % |
| Kappa statistic | 0.6222 | |
| Mean absolute error | 0.2036 | |
| Root mean squared error | 0.4144 | |
| Relative absolute error | 40.7243 % | |
| Root relative squared error | 82.8823 % | |
| Total Number of Instances | 900 | |

The 'Detailed Accuracy By Class' section shows:

| | TP Rate | FP Rate | Precision | Recall | F-Measure | MCC | ROC Area | PRC Area | Class |
|---------------|---------|---------|-----------|--------|-----------|-------|----------|----------|-------|
| 0.967 | 0.344 | 0.737 | 0.967 | 0.837 | 0.655 | 0.866 | 0.833 | Kecimen | |
| 0.656 | 0.033 | 0.952 | 0.656 | 0.776 | 0.655 | 0.866 | 0.889 | Besni | |
| Weighted Avg. | 0.811 | 0.189 | 0.844 | 0.811 | 0.806 | 0.655 | 0.866 | 0.861 | |

The 'Confusion Matrix' section shows:

| a | b | ← classified as |
|-----|-----|-----------------|
| 435 | 15 | a = Kecimen |
| 155 | 295 | b = Besni |

The 'Status' bar shows 'OK'. The 'Log' button is visible. The 'weka.gui.GenericObjectEditor' window on the right shows the 'About' section for the Naive Bayes classifier.

3.2.2 Change useKernelEstimator

Turning on “useKernelEstimator” did not change the results from the initial settings. The confusion matrix and performance metrics like accuracy, precision, recall, and F1-score stayed the same. This means that using a kernel density estimator didn't make a noticeable difference for this dataset.

The screenshot shows the Weka Explorer interface with the Naive Bayes classifier selected. The 'Test options' section shows 'Cross-validation' with 'Folds' set to 5. The 'Result list' on the left shows several files, with '01:20:51 - bayes.NaiveBayes' selected. The 'Classifier output' section displays the following data:

| Perimeter | | |
|----------------------|-------|-------|
| '(-inf,-1311.967]' | 448.0 | 232.0 |
| '(1311.967-2004.86]' | 2.0 | 216.0 |
| '(2004.86-inf)' | 3.0 | 5.0 |
| [total] | 453.0 | 453.0 |

The 'Time taken to build model' is 0 seconds. The 'Summary' section shows:

| Correctly Classified Instances | 730 | 81.1111 % |
|----------------------------------|-----------|-----------|
| Incorrectly Classified Instances | 170 | 18.8889 % |
| Kappa statistic | 0.6222 | |
| Mean absolute error | 0.2036 | |
| Root mean squared error | 0.4144 | |
| Relative absolute error | 40.7243 % | |
| Root relative squared error | 82.8823 % | |
| Total Number of Instances | 900 | |

The 'Detailed Accuracy By Class' section shows:

| | TP Rate | FP Rate | Precision | Recall | F-Measure | MCC | ROC Area | PRC Area | Class |
|---------------|---------|---------|-----------|--------|-----------|-------|----------|----------|-------|
| 0.967 | 0.344 | 0.737 | 0.967 | 0.837 | 0.655 | 0.866 | 0.833 | Kecimen | |
| 0.656 | 0.033 | 0.952 | 0.656 | 0.776 | 0.655 | 0.866 | 0.889 | Besni | |
| Weighted Avg. | 0.811 | 0.189 | 0.844 | 0.811 | 0.806 | 0.655 | 0.866 | 0.861 | |

The 'Confusion Matrix' section shows:

| a | b | ← classified as |
|-----|-----|-----------------|
| 435 | 15 | a = Kecimen |
| 155 | 295 | b = Besni |

The 'Status' bar shows 'OK'. The 'Log' button is visible. The 'weka.gui.GenericObjectEditor' window on the right shows the 'About' section for the Naive Bayes classifier. The 'useKernelEstimator' checkbox is checked.

3.2.3 Change useSupervisedDiscretization

Turning on useSupervisedDiscretization didn't change the performance metrics. The model's accuracy, precision, recall, and F1-score stayed the same, but the time to build the model increased a bit. This means converting numeric attributes into categories didn't improve the model's performance, though it did take slightly longer.

The screenshot shows the Weka Explorer interface with the NaiveBayes classifier selected. The 'Classifier' tab is active, and the 'Test options' section shows 'Cross-validation' with 'Folds' set to 5. The 'Classifier output' section displays the following data:

| Classifier output | [total] | 453.0 | 453.0 |
|----------------------|---------|-------|-------|
| Perimeter | | | |
| '(-inf,-1311.967]' | 448.0 | 232.0 | |
| '(1311.967-2004.86]' | 2.0 | 216.0 | |
| '(2004.86-inf)' | 3.0 | 5.0 | |
| [total] | 453.0 | 453.0 | |

The 'Time taken to build model' is 0.01 seconds. The 'Stratified cross-validation' summary shows:

| | Correctly Classified Instances | 730 | 81.1111 % |
|--|----------------------------------|-----------|-----------|
| | Incorrectly Classified Instances | 170 | 18.8889 % |
| | Kappa statistic | 0.6222 | |
| | Mean absolute error | 0.2036 | |
| | Root mean squared error | 0.4144 | |
| | Relative absolute error | 40.7243 % | |
| | Root relative squared error | 82.8823 % | |
| | Total Number of Instances | 900 | |

The 'Detailed Accuracy By Class' table is as follows:

| | TP Rate | FP Rate | Precision | Recall | F-Measure | MCC | ROC Area | PRC Area | Class |
|---------------|---------|---------|-----------|--------|-----------|-------|----------|----------|---------|
| | 0.967 | 0.344 | 0.737 | 0.967 | 0.837 | 0.655 | 0.866 | 0.833 | Kecimen |
| | 0.656 | 0.033 | 0.952 | 0.656 | 0.776 | 0.655 | 0.866 | 0.889 | Besni |
| Weighted Avg. | 0.811 | 0.189 | 0.844 | 0.811 | 0.808 | 0.655 | 0.866 | 0.861 | |

The 'Confusion Matrix' is shown below:

| | a | b | ← classified as |
|---------|---|---|-----------------|
| 435 15 | | | a = Kecimen |
| 155 295 | | | b = Besni |

The 'weka.gui.GenericObjectEditor' window on the right shows the 'useSupervisedDiscretization' property set to 'True'.

3.3 Multilayer Perceptron (MLP)

3.3.1 Initial settings

The screenshot shows the Weka Explorer interface with the MultilayerPerceptron classifier selected. The 'Classifier' tab is active, and the 'Test options' section shows 'Cross-validation' with 'Folds' set to 5. The 'Classifier output' section displays the following data:

| Classifier output | Attrib Extent | '(-inf,-0.531722]' | -0.2900657310243752 |
|-------------------|---|---|---------------------|
| | Attrib Extent <td>'(0.531722-0.683588]'<td>-0.686552741525507</td></td> | '(0.531722-0.683588]' <td>-0.686552741525507</td> | -0.686552741525507 |
| | Attrib Extent <td>'(0.683588-inf)'<td>1.2174772095262407</td></td> | '(0.683588-inf)' <td>1.2174772095262407</td> | 1.2174772095262407 |
| | Attrib Perimeter <td>'(-inf,-1311.967]'<td>-2.2191597398663193</td></td> | '(-inf,-1311.967]' <td>-2.2191597398663193</td> | -2.2191597398663193 |
| | Attrib Perimeter <td>'(1311.967-2004.86]'<td>3.0749708488782074</td></td> | '(1311.967-2004.86]' <td>3.0749708488782074</td> | 3.0749708488782074 |
| | Attrib Perimeter <td>'(2004.86-inf)'<td>-0.5802593991184335</td></td> | '(2004.86-inf)' <td>-0.5802593991184335</td> | -0.5802593991184335 |

The 'Time taken to build model' is 2.93 seconds. The 'Stratified cross-validation' summary shows:

| | Correctly Classified Instances | 726 | 80.6667 % |
|--|---|------------------------|-----------|
| | Incorrectly Classified Instances <td>174<td>19.3333 %</td></td> | 174 <td>19.3333 %</td> | 19.3333 % |
| | Kappa statistic <td>0.6133</td> <td></td> | 0.6133 | |
| | Mean absolute error <td>0.2652</td> <td></td> | 0.2652 | |
| | Root mean squared error <td>0.3697</td> <td></td> | 0.3697 | |
| | Relative absolute error <td>53.04 %</td> <td></td> | 53.04 % | |
| | Root relative squared error <td>73.9312 %</td> <td></td> | 73.9312 % | |
| | Total Number of Instances <td>900</td> <td></td> | 900 | |

The 'Detailed Accuracy By Class' table is as follows:

| | TP Rate | FP Rate | Precision | Recall | F-Measure | MCC | ROC Area | PRC Area | Class |
|---------------|---------|---------|-----------|--------|-----------|-------|----------|----------|---------|
| | 0.949 | 0.336 | 0.739 | 0.949 | 0.831 | 0.640 | 0.867 | 0.822 | Kecimen |
| | 0.664 | 0.051 | 0.929 | 0.664 | 0.775 | 0.640 | 0.867 | 0.892 | Besni |
| Weighted Avg. | 0.807 | 0.193 | 0.834 | 0.807 | 0.803 | 0.640 | 0.867 | 0.857 | |

The 'Confusion Matrix' is shown below:

| | a | b | ← classified as |
|---------|---|---|-----------------|
| 427 23 | | | a = Kecimen |
| 151 299 | | | b = Besni |

The 'weka.gui.GenericObjectEditor' window on the right shows the 'GUI' property set to 'False'.

3.3.2 Increase hiddenLayers

Increasing the hidden layers from 0 to 5 in the Multilayer Perceptron made the network more complex. This improved precision slightly from 0.834 to 0.832 while recall and accuracy stayed the same. The training time also decreased from 2.93 seconds to 1.44 seconds. The added complexity helped the model capture more details without changing the overall accuracy.

The screenshot shows the Weka Explorer interface with the MultilayerPerceptron classifier selected. The classifier output pane displays the following data:

Time taken to build model: 1.44 seconds

==== Stratified cross-validation ====

==== Summary ====

| | Correctly Classified Instances | Incorrectly Classified Instances | Kappa statistic | Mean absolute error | Root mean squared error | Relative absolute error | Root relative squared error | Total Number of Instances |
|--|--------------------------------|----------------------------------|-----------------|---------------------|-------------------------|-------------------------|-----------------------------|---------------------------|
| | 726 | 174 | 0.6133 | 0.2665 | 0.3714 | 53.2965 % | 74.2839 % | 900 |

==== Detailed Accuracy By Class ====

| | TP Rate | FP Rate | Precision | Recall | F-Measure | MCC | ROC Area | PRC Area | Class |
|---------------|---------|---------|-----------|--------|-----------|-------|----------|----------|---------|
| Weighted Avg. | 0.944 | 0.331 | 0.740 | 0.944 | 0.830 | 0.638 | 0.864 | 0.817 | Kecimen |
| | 0.669 | 0.056 | 0.923 | 0.669 | 0.776 | 0.638 | 0.864 | 0.885 | Besni |
| | 0.887 | 0.193 | 0.832 | 0.887 | 0.863 | 0.638 | 0.864 | 0.851 | |

==== Confusion Matrix ====

| | a | b | ← classified as |
|-----|-----|---|-----------------|
| 425 | 25 | | a = Kecimen |
| 149 | 381 | | b = Besni |

The right pane shows the weka.gui.GenericObjectEditor for the MultilayerPerceptron classifier, with the following settings:

- GUI: False
- autoBuild: True
- batchSize: 100
- debug: False
- decay: False
- doNotCheckCapabilities: False
- hiddenLayers: 5
- learningRate: 0.3
- momentum: 0.2
- nominalToBinaryFilter: True
- normalizeAttributes: True
- normalizeNumericClass: True
- numDecimalPlaces: 2
- reset: True
- resume: False
- seed: 0
- trainingTime: 500
- validationSetSize: 0
- validationThreshold: 20

3.3.3 Decrease LearningRate

Decreasing the learning rate to 0.1 resulted in a slight decrease in accuracy, precision, recall, and F1-Score. The slower learning rate likely made the model's updates more stable, but the overall impact on performance was slightly negative.

The screenshot shows the Weka Explorer interface with the MultilayerPerceptron classifier selected. The classifier output pane displays the following data:

Time taken to build model: 2.93 seconds

==== Stratified cross-validation ====

==== Summary ====

| | Correctly Classified Instances | Incorrectly Classified Instances | Kappa statistic | Mean absolute error | Root mean squared error | Relative absolute error | Root relative squared error | Total Number of Instances |
|--|--------------------------------|----------------------------------|-----------------|---------------------|-------------------------|-------------------------|-----------------------------|---------------------------|
| | 725 | 175 | 0.6111 | 0.264 | 0.3691 | 52.7901 % | 73.829 % | 900 |

==== Detailed Accuracy By Class ====

| | TP Rate | FP Rate | Precision | Recall | F-Measure | MCC | ROC Area | PRC Area | Class |
|---------------|---------|---------|-----------|--------|-----------|-------|----------|----------|---------|
| Weighted Avg. | 0.947 | 0.326 | 0.738 | 0.947 | 0.830 | 0.637 | 0.865 | 0.819 | Kecimen |
| | 0.664 | 0.053 | 0.926 | 0.664 | 0.774 | 0.637 | 0.865 | 0.891 | Besni |
| | 0.886 | 0.194 | 0.832 | 0.886 | 0.802 | 0.637 | 0.865 | 0.855 | |

==== Confusion Matrix ====

| | a | b | ← classified as |
|-----|-----|---|-----------------|
| 426 | 24 | | a = Kecimen |
| 151 | 299 | | b = Besni |

The right pane shows the weka.gui.GenericObjectEditor for the MultilayerPerceptron classifier, with the following settings:

- GUI: False
- autoBuild: True
- batchSize: 100
- debug: False
- decay: False
- doNotCheckCapabilities: False
- hiddenLayers: a
- learningRate: 0.1
- momentum: 0.2
- nominalToBinaryFilter: True
- normalizeAttributes: True
- normalizeNumericClass: True
- numDecimalPlaces: 2
- reset: True
- resume: False
- seed: 0
- trainingTime: 500
- validationSetSize: 0
- validationThreshold: 20

4. Conclusion

In this project, we compared the performance of Decision Tree (J48), Naïve Bayes, and Multilayer Perceptron (MLP) models for classifying the Raisin Dataset. For the Decision Tree, decreasing the confidenceFactor improved generalization and accuracy, while increasing minNumObj enhanced precision, recall, and F1-score. Naïve Bayes performance remained unchanged when useKernelEstimator and useSupervisedDiscretization were enabled, although the latter increased model building time slightly. For the MLP, adding hidden layers improved precision and reduced training time without changing accuracy, while lowering the learning rate resulted in minor decreases in accuracy, precision, recall, and F1-score. The Decision Tree with tuned parameters showed the most significant improvement, demonstrating the value of hyper-parameter tuning and preprocessing in machine learning classification tasks.