SUPERVISED LEARNING

Introduction:

**Supervised learning** is the machine learning task of learning a function that maps an input to an output based on example input-output pairs. It infers a function from labeled training data consisting of a set of training examples. In supervised learning, each example is a pair consisting of an input object (typically a vector) and a desired output value (also called the supervisory signal). A supervised learning algorithm analyzes the training data and produces an inferred function, which can be used for mapping new examples. An optimal scenario will allow for the algorithm to correctly determine the class labels for unseen instances. This requires the learning algorithm to generalize from the training data to unseen situations in a "reasonable" way. The parallel task in human and animal psychology is often referred to as concept learning.

**Abstraction:**

In this supervised learning, focused on the following criteria based on some issues:

* COMPACTNESS
* CIRCULARITY
* DISTANCE CIRCULARITY
* RADIUS RATIO
* PR.AXIS ASPECT RATIO
* MAX.LENGTH ASPECT RATIO
* SCATTER RATIO
* ELONGATEDNESS
* PR.AXIS RECTANGULARITY
* MAX.LENGTH RECTANGULARITY
* SCALED VARIANCE ALONG MAJOR AXIS
* SCALED VARIANCE ALONG MINOR AXIS
* SCALED RADIUS OF GYRATION
* SKEWNESS ABOUT MAJOR AXIS
* SKEWNESS ABOUT MINOR AXIS
* KURTOSIS ABOUT MINOR AXIS
* KURTOSIS ABOUT MAJOR AXIS
* HOLLOWS RATIO

Here, based on this parameters, the efficiency of four different algorithms for this case was tested and implemented and there are results given in result portion. According to analysis, here **J48** is best for the given dataset and given requirements. The rule tree classification performance compared favourably to MDC (Minimum Distance Classifier) & k-NN (k- Nearest Neighbour) statistical classifiers in terms of both error rate and computational efficiency. An investigation of these rule trees generated by example indicated that the tree structure was heavily influenced by the orientation of the objects, and grouped similar object views into single decisions.

**Data Set Information:**

The purpose is to classify a given silhouette as one of four types of vehicle, using a set of features extracted from the silhouette. The vehicle may be viewed from one of many different angles.

* **History:**

This data was originally gathered at the TI in 1986-87 by JP Siebert. It was partially financed by Barr and Stroud Ltd. The original purpose was to find a method of distinguishing 3D objects within a 2D image by application of an ensemble of shape feature extractors to the 2D silhouettes of the objects. Measures of shape features extracted from example silhouettes of objects to be discriminated were used to generate a classification rule tree by means of computer induction.

This object recognition strategy was successfully used to discriminate between silhouettes of model cars, vans and buses viewed from constrained elevation but all angles of rotation.

The rule tree classification performance compared favourably to MDC (Minimum Distance Classifier) and k-NN (k-Nearest Neighbour) statistical classifiers in terms of both error rate and computational efficiency. An investigation of these rule trees generated by example indicated that the tree structure was heavily influenced by the orientation of the objects and grouped similar object views into single decisions.

* **Description:**

The features were extracted from the silhouettes by the HIPS (Hierarchical Image Processing System) extension BINATTS, which extracts a combination of scale independent features utilizing both classical moments based measures such as scaled variance, skewness and kurtosis about the major/minor axes and heuristic measures such as hollows, circularity, rectangularity and compactness.

Four "Corgie" model vehicles were used for the experiment: a double decker bus, Cheverolet van, Saab 9000 and an Opel Manta 400. This particular combination of vehicles was chosen with the expectation that the bus, van and either one of the cars would be readily distinguishable, but it would be more difficult to distinguish between the cars.

The images were acquired by a camera looking downwards at the model vehicle from a fixed angle of elevation (34.2 degrees to the horizontal). The vehicles were placed on a diffuse backlit surface (light box). The vehicles were painted matte black to minimize highlights. The images were captured using a CRS4000 frame store connected to a vax 750. All images were captured with a spatial resolution of 128x128 pixels quantized to 64 grey levels. These images were thresholded to produce binary vehicle silhouettes, negated (to comply with the processing requirements of BINATTS) and thereafter subjected to shrink-expand-expand-shrink HIPS modules to remove "salt and pepper" image noise.

The vehicles were rotated and their angle of orientation was measured using a radial graticule beneath the vehicle. 0 and 180 degrees corresponded to "head on" and "rear" views respectively while 90 and 270 corresponded to profiles in opposite directions. Two sets of 60 images, each set covering a full 360 degree rotation, were captured for each vehicle. The vehicle was rotated by a fixed angle between images. These datasets are known as e2 and e3 respectively.

A further two sets of images, e4 and e5, were captured with the camera at elevations of 37.5 degrees and 30.8 degrees respectively. These sets also contain 60 images per vehicle apart from e4.van which contains only 46 owing to the difficulty of containing the van in the image at some orientations.

**Attribute Information:**

* **Attributes:**
* COMPACTNESS (average perim)\*\*2/area
* CIRCULARITY (average radius)\*\*2/area
* DISTANCE CIRCULARITY area/(av.distance from border)\*\*2
* RADIUS RATIO (max.rad-min.rad)/av.radius
* PR.AXIS ASPECT RATIO (minor axis)/(major axis)
* MAX.LENGTH ASPECT RATIO (length perp. max length)/(max length)
* SCATTER RATIO (inertia about minor axis)/(inertia about major axis)
* ELONGATEDNESS area/(shrink width)\*\*2
* PR.AXIS RECTANGULARITY area/(pr.axis length\*pr.axis width)
* MAX.LENGTH RECTANGULARITY area/(max.length\*length perp. to this)
* SCALED VARIANCE (2nd order moment about minor axis)/area

ALONG MAJOR AXIS

* SCALED VARIANCE (2nd order moment about major axis)/area

ALONG MINOR AXIS

* SCALED RADIUS OF GYRATION (mavar+mivar)/area
* SKEWNESS ABOUT (3rd order moment about major axis)/sigma\_min\*\*3

MAJOR AXIS

* SKEWNESS ABOUT (3rd order moment about minor axis)/sigma\_maj\*\*3

MINOR AXIS

* KURTOSIS ABOUT (4th order moment about major axis)/sigma\_min\*\*4

MINOR AXIS

* KURTOSIS ABOUT (4th order moment about minor axis)/sigma\_maj\*\*4

MAJOR AXIS

* HOLLOWS RATIO (area of hollows)/(area of bounding polygon)

The area of the bounding polygon is found as a side result of the computation to find the maximum length. Each individual length computation yields a pair of calipers to the object orientated at every 5 degrees. The object is propagated into an image containing the union of these calipers to obtain an image of the bounding polygon.

* **Number Of Classes:**

4 - OPEL, SAAB, BUS, VAN

* **Number Of Examples:**

Total no. = 946

No. in each class

opel 240

saab 240

bus 240

van 226

100 examples are being kept by Strathclyde for validation.

* **Number Of Attributes:**

No. of attributes = 18

1. **Scheme: weka.classifiers.bayes.NaiveBayes**

Relation: Vehicle Silhouettes

Instances: 846

Attributes: 19

COMPACTNESS

CIRCULARITY

DISTANCE CIRCULARITY

RADIUS RATIO

PR.AXIS ASPECT RATIO

MAX.LENGTH ASPECT RATIO

SCATTER RATIO

ELONGATEDNESS

PR.AXIS RECTANGULARITY

MAX.LENGTH RECTANGULARITY

SCALED VARIANCE MAJOR

SCALED VARIANCE MINOR

SCALED RADIUS OF GYRATION

SKEWNESS ABOUT MAJOR

SKEWNESS ABOUT MINOR

KURTOSIS ABOUT MINOR

KURTOSIS ABOUT MAJOR

HOLLOWS RATIO

CLASS

Test mode: 10-fold cross-validation

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

Naive Bayes Classifier

Class

Attribute van saab bus opel

(0.24) (0.26) (0.26) (0.25)

================================================================

COMPACTNESS

mean 90.5056 97.2453 91.578 94.9974

std. dev. 4.0111 9.0909 8.6065 8.1774

weight sum 199 217 218 212

precision 1.0698 1.0698 1.0698 1.0698

CIRCULARITY

mean 42.0704 45.5346 45.0688 46.5802

std. dev. 4.0728 6.8034 5.0192 7.2182

weight sum 199 217 218 212

precision 1 1 1 1

DISTANCE CIRCULARITY

mean 73.3189 88.6541 76.7197 89.0743

std. dev. 10.8137 17.026 12.0292 15.5555

weight sum 199 217 218 212

precision 1.1613 1.1613 1.1613 1.1613

RADIUS RATIO

mean 147.0802 180.853 166.0278 180.2859

std. dev. 29.8102 30.7223 30.4572 31.2924

weight sum 199 217 218 212

precision 1.7218 1.7218 1.7218 1.7218

PR.AXIS ASPECT RATIO

mean 61.2891 61.2258 63.4264 61.0721

std. dev. 11.4274 4.3862 8.8268 5.0572

weight sum 199 217 218 212

precision 2.5278 2.5278 2.5278 2.5278

MAX.LENGTH ASPECT RATIO

mean 9.6412 8.8903 7.1842 8.925

std. dev. 7.1185 2.2589 4.8718 2.0855

weight sum 199 217 218 212

precision 2.65 2.65 2.65 2.65

SCATTER RATIO

mean 141.5383 179.695 169.979 182.1733

std. dev. 13.9536 31.4383 33.2899 32.7443

weight sum 199 217 218 212

precision 1.1769 1.1769 1.1769 1.1769

ELONGATEDNESS

mean 48.1289 38.3681 40.2651 37.9134

std. dev. 4.493 7.5772 6.6772 7.8238

weight sum 199 217 218 212

precision 1.0294 1.0294 1.0294 1.0294

PR.AXIS RECTANGULARITY

mean 18.5779 21.447 20.5734 21.5896

std. dev. 1.0286 2.4473 2.7221 2.547

weight sum 199 217 218 212

precision 1 1 1 1

MAX.LENGTH RECTANGULARITY

mean 145.2006 148.6898 146.7876 151.2772

std. dev. 11.0053 16.0797 10.4646 18.0956

weight sum 199 217 218 212

precision 1.0769 1.0769 1.0769 1.0769

SCALED VARIANCE MAJOR

mean 164.1234 197.1011 192.9029 198.5741

std. dev. 19.6532 27.7863 33.8236 28.6335

weight sum 199 217 218 212

precision 1.4961 1.4961 1.4961 1.4961

SCALED VARIANCE MINOR

mean 298.2018 493.7891 448.8265 508.4762

std. dev. 55.8744 162.7785 192.7775 172.0663

weight sum 199 217 218 212

precision 1.9716 1.9716 1.9716 1.9716

SCALED RADIUS OF GYRATION

mean 157.2501 179.3974 180.9989 179.7782

std. dev. 22.7642 33.6916 31.1784 34.684

weight sum 199 217 218 212

precision 1.1197 1.1197 1.1197 1.1197

SKEWNESS ABOUT MAJOR

mean 72.8342 69.8065 77.055 70.2358

std. dev. 8.8634 5.3088 7.7345 5.1799

weight sum 199 217 218 212

precision 2 2 2 2

SKEWNESS ABOUT MINOR

mean 6.4171 7.659 4.844 6.6038

std. dev. 4.6541 5.8035 3.2131 5.181

weight sum 199 217 218 212

precision 1 1 1 1

KURTOSIS ABOUT MINOR

mean 9.8791 15.3419 10.3769 15.0462

std. dev. 6.2513 9.9013 6.8491 10.0009

weight sum 199 217 218 212

precision 1.025 1.025 1.025 1.025

KURTOSIS ABOUT MAJOR

mean 189.0348 189.8729 187.8061 189.4275

std. dev. 6.259 4.8815 7.1897 5.4966

weight sum 199 217 218 212

precision 1.0345 1.0345 1.0345 1.0345

HOLLOWS RATIO

mean 196.1457 198.0415 191.3257 197.1132

std. dev. 7.3268 6.5951 7.9001 5.8323

weight sum 199 217 218 212

precision 1 1 1 1

Time taken to build model: 0.02 seconds

=== Summary ===

Correctly Classified Instances 379 44.7991 %

Incorrectly Classified Instances 467 55.2009 %

Kappa statistic 0.2697

Mean absolute error 0.2826

Root mean squared error 0.462

Relative absolute error 75.4027 %

Root relative squared error 106.7136 %

Total Number of Instances 846

=== Detailed Accuracy By Class ===

TP Rate FP Rate Precision Recall F-Measure MCC ROC Area PRC Area Class

0.874 0.411 0.395 0.874 0.545 0.393 0.821 0.529 van

0.392 0.119 0.531 0.392 0.451 0.304 0.712 0.494 saab

0.147 0.027 0.653 0.147 0.240 0.224 0.843 0.609 bus

0.415 0.172 0.447 0.415 0.430 0.249 0.702 0.449 opel

Weighted Avg. 0.448 0.177 0.510 0.448 0.413 0.291 0.769 0.521

=== Confusion Matrix ===

a b c d <-- classified as

174 7 14 4 | a = van

67 85 3 62 | b = saab

135 8 32 43 | c = bus

64 60 0 88 | d = opel

1. **Scheme: weka.classifiers.lazy.IBk -K 1 -W 0 –A "weka.core.neighboursearch.LinearNNSearch –A \"weka.core.EuclideanDistance -R first-last\""**

Relation: Vehicle Silhouettes

Instances: 846

Attributes: 19

COMPACTNESS

CIRCULARITY

DISTANCE CIRCULARITY

RADIUS RATIO

PR.AXIS ASPECT RATIO

MAX.LENGTH ASPECT RATIO

SCATTER RATIO

ELONGATEDNESS

PR.AXIS RECTANGULARITY

MAX.LENGTH RECTANGULARITY

SCALED VARIANCE MAJOR

SCALED VARIANCE MINOR

SCALED RADIUS OF GYRATION

SKEWNESS ABOUT MAJOR

SKEWNESS ABOUT MINOR

KURTOSIS ABOUT MINOR

KURTOSIS ABOUT MAJOR

HOLLOWS RATIO

CLASS

Test mode: 10-fold cross-validation

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

IB1 instance-based classifier

using 1 nearest neighbour(s) for classification

Time taken to build model: 0 seconds

=== Stratified cross-validation ===

=== Summary ===

Correctly Classified Instances 591 69.8582 %

Incorrectly Classified Instances 255 30.1418 %

Kappa statistic 0.598

Mean absolute error 0.1519

Root mean squared error 0.3872

Relative absolute error 40.5184 %

Root relative squared error 89.4389 %

Total Number of Instances 846

=== Detailed Accuracy By Class ===

TP Rate FP Rate Precision Recall F-Measure MCC ROC Area PRC Area Class

0.894 0.048 0.852 0.894 0.873 0.833 0.927 0.795 van

0.498 0.170 0.502 0.498 0.500 0.329 0.669 0.391 saab

0.931 0.037 0.898 0.931 0.914 0.884 0.952 0.871 bus

0.481 0.148 0.520 0.481 0.500 0.342 0.666 0.396 opel

Weighted Avg. 0.699 0.101 0.691 0.699 0.694 0.594 0.802 0.611

=== Confusion Matrix ===

a b c d <-- classified as

178 10 6 5 | a = van

13 108 11 85 | b = saab

8 3 203 4 | c = bus

10 94 6 102| d = opel

1. **Scheme: weka.classifiers.trees.BFTree -M 2 -N 5 -C 1.0 -P POSTPRUNED -S 1**

Relation: Vehicle Silhouettes

Instances: 846

Attributes: 19

COMPACTNESS

CIRCULARITY

DISTANCE CIRCULARITY

RADIUS RATIO

PR.AXIS ASPECT RATIO

MAX.LENGTH ASPECT RATIO

SCATTER RATIO

ELONGATEDNESS

PR.AXIS RECTANGULARITY

MAX.LENGTH RECTANGULARITY

SCALED VARIANCE MAJOR

SCALED VARIANCE MINOR

SCALED RADIUS OF GYRATION

SKEWNESS ABOUT MAJOR

SKEWNESS ABOUT MINOR

KURTOSIS ABOUT MINOR

KURTOSIS ABOUT MAJOR

HOLLOWS RATIO

CLASS

Test mode: 10-fold cross-validation

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

Best-First Decision Tree

ELONGATEDNESS < 41.5

| MAX.LENGTH ASPECT RATIO < 7.5

| | COMPACTNESS < 95.5

| | | PR.AXIS ASPECT RATIO < 67.5

| | | | SCATTER RATIO < 161.5: saab(5.0/0.0)

| | | | SCATTER RATIO >= 161.5

| | | | | COMPACTNESS < 89.5: opel(5.0/0.0)

| | | | | COMPACTNESS >= 89.5

| | | | | | SCATTER RATIO < 167.5: opel(4.0/1.0)

| | | | | | SCATTER RATIO >= 167.5: saab(5.0/1.0)

| | | PR.AXIS ASPECT RATIO >= 67.5: bus(16.0/0.0)

| | COMPACTNESS >= 95.5: bus(69.0/1.0)

| MAX.LENGTH ASPECT RATIO >= 7.5

| | COMPACTNESS < 106.5

| | | MAX.LENGTH RECTANGULARITY < 173.5

| | | | HOLLOWS RATIO < 195.5

| | | | | SCATTER RATIO < 176.5

| | | | | | COMPACTNESS < 93.5

| | | | | | | COMPACTNESS < 89.5: opel(2.0/1.0)

| | | | | | | COMPACTNESS >= 89.5: saab(4.0/0.0)

| | | | | | COMPACTNESS >= 93.5: opel(2.0/0.0)

| | | | | SCATTER RATIO >= 176.5: opel(20.0/2.0)

| | | | HOLLOWS RATIO >= 195.5

| | | | | SKEWNESS ABOUT MINOR < 13.5

| | | | | | SCALED VARIANCE MAJOR < 183.5: opel(4.0/0.0)

| | | | | | SCALED VARIANCE MAJOR >= 183.5

| | | | | | | HOLLOWS RATIO < 206.5

| | | | | | | | SCALED RADIUS OF GYRATION < 218.5

| | | | | | | | | MAX.LENGTH RECTANGULARITY < 152.5: saab(27.0/20.0)

| | | | | | | | | MAX.LENGTH RECTANGULARITY >= 152.5

| | | | | | | | | | SKEWNESS ABOUT MINOR < 3.5

| | | | | | | | | | | SCALED RADIUS OF GYRATION < 183.5: opel(5.0/0.0)

| | | | | | | | | | | SCALED RADIUS OF GYRATION >= 183.5

| | | | | | | | | | | | DISTANCE CIRCULARITY < 99.0

| | | | | | | | | | | | | KURTOSIS ABOUT MINOR < 12.0: saab(2.0/0.0)

| | | | | | | | | | | | | KURTOSIS ABOUT MINOR >= 12.0: opel(5.0/0.0)

| | | | | | | | | | | | DISTANCE CIRCULARITY >= 99.0

| | | | | | | | | | | | | KURTOSIS ABOUT MAJOR < 190.5: saab(11.0/0.0)

| | | | | | | | | | | | | KURTOSIS ABOUT MAJOR >= 190.5: opel(3.0/1.0)

| | | | | | | | | | SKEWNESS ABOUT MINOR >= 3.5: opel(26.0/6.0)

| | | | | | | | SCALED RADIUS OF GYRATION >= 218.5

| | | | | | | | | SCALED RADIUS OF GYRATION < 240.5

| | | | | | | | | | SKEWNESS ABOUT MINOR < 11.0: saab(15.0/1.0)

| | | | | | | | | | SKEWNESS ABOUT MINOR >= 11.0: opel(2.0/1.0)

| | | | | | | | | SCALED RADIUS OF GYRATION >= 240.5: opel(4.0/0.0)

| | | | | | | HOLLOWS RATIO >= 206.5: saab(9.0/1.0)

| | | | | SKEWNESS ABOUT MINOR >= 13.5

| | | | | | SCATTER RATIO < 184.5

| | | | | | | SCALED VARIANCE MAJOR < 191.5: saab(2.0/0.0)

| | | | | | | SCALED VARIANCE MAJOR >= 191.5: opel(3.0/0.0)

| | | | | | SCATTER RATIO >= 184.5: saab(11.0/0.0)

| | | MAX.LENGTH RECTANGULARITY >= 173.5: opel(29.0/1.0)

| | COMPACTNESS >= 106.5

| | | SCALED RADIUS OF GYRATION < 212.5

| | | | KURTOSIS ABOUT MINOR < 6.5

| | | | | MAX.LENGTH ASPECT RATIO < 11.5: opel(8.0/1.0)

| | | | | MAX.LENGTH ASPECT RATIO >= 11.5: saab(2.0/0.0)

| | | | KURTOSIS ABOUT MINOR >= 6.5

| | | | | KURTOSIS ABOUT MAJOR < 194.5

| | | | | | RADIUS RATIO < 191.5: saab(1.0/1.0)

| | | | | | RADIUS RATIO >= 191.5: saab(14.0/0.0)

| | | | | KURTOSIS ABOUT MAJOR >= 194.5: opel(2.0/0.0)

| | | SCALED RADIUS OF GYRATION >= 212.5: saab(25.0/1.0)

ELONGATEDNESS >= 41.5

| MAX.LENGTH ASPECT RATIO < 8.5

| | SCALED VARIANCE MINOR < 308.5

| | | MAX.LENGTH RECTANGULARITY < 131.5

| | | | COMPACTNESS < 81.5

| | | | | SCATTER RATIO < 140.5: opel(11.0/0.0)

| | | | | SCATTER RATIO >= 140.5: saab(2.0/0.0)

| | | | COMPACTNESS >= 81.5

| | | | | PR.AXIS RECTANGULARITY < 17.5

| | | | | | KURTOSIS ABOUT MINOR < 19.5

| | | | | | | SKEWNESS ABOUT MINOR < 16.5

| | | | | | | | SCALED VARIANCE MINOR < 219.5: van(13.0/0.0)

| | | | | | | | SCALED VARIANCE MINOR >= 219.5: van(3.0/1.0)

| | | | | | | SKEWNESS ABOUT MINOR >= 16.5: opel(2.0/0.0)

| | | | | | KURTOSIS ABOUT MINOR >= 19.5

| | | | | | | MAX.LENGTH RECTANGULARITY < 124.0: saab(5.0/0.0)

| | | | | | | MAX.LENGTH RECTANGULARITY >= 124.0: van(2.0/1.0)

| | | | | PR.AXIS RECTANGULARITY >= 17.5

| | | | | | SCALED RADIUS OF GYRATION < 131.0

| | | | | | | MAX.LENGTH RECTANGULARITY < 128.5

| | | | | | | | KURTOSIS ABOUT MINOR < 24.5

| | | | | | | | | CIRCULARITY < 34.5: saab(2.0/0.0)

| | | | | | | | | CIRCULARITY >= 34.5: opel(3.0/1.0)

| | | | | | | | KURTOSIS ABOUT MINOR >= 24.5: opel(5.0/0.0)

| | | | | | | MAX.LENGTH RECTANGULARITY >= 128.5: van(5.0/1.0)

| | | | | | SCALED RADIUS OF GYRATION >= 131.0

| | | | | | | CIRCULARITY < 37.5

| | | | | | | | MAX.LENGTH ASPECT RATIO < 7.5: saab(12.0/0.0)

| | | | | | | | MAX.LENGTH ASPECT RATIO >= 7.5: saab(1.0/1.0)

| | | | | | | CIRCULARITY >= 37.5

| | | | | | | | COMPACTNESS < 85.0: opel(3.0/0.0)

| | | | | | | | COMPACTNESS >= 85.0: saab(2.0/1.0)

| | | MAX.LENGTH RECTANGULARITY >= 131.5

| | | | SCATTER RATIO < 139.5

| | | | | MAX.LENGTH RECTANGULARITY < 138.5

| | | | | | SCALED RADIUS OF GYRATION < 149.0: van(19.0/2.0)

| | | | | | SCALED RADIUS OF GYRATION >= 149.0

| | | | | | | SCALED VARIANCE MAJOR < 148.5: van(3.0/0.0)

| | | | | | | SCALED VARIANCE MAJOR >= 148.5

| | | | | | | | MAX.LENGTH RECTANGULARITY < 135.5: saab(4.0/0.0)

| | | | | | | | MAX.LENGTH RECTANGULARITY >= 135.5: opel(3.0/1.0)

| | | | | MAX.LENGTH RECTANGULARITY >= 138.5: van(37.0/0.0)

| | | | SCATTER RATIO >= 139.5

| | | | | MAX.LENGTH RECTANGULARITY < 146.5

| | | | | | KURTOSIS ABOUT MINOR < 16.5

| | | | | | | SKEWNESS ABOUT MINOR < 9.5: bus(3.0/1.0)

| | | | | | | SKEWNESS ABOUT MINOR >= 9.5: saab(4.0/1.0)

| | | | | | KURTOSIS ABOUT MINOR >= 16.5: opel(3.0/1.0)

| | | | | MAX.LENGTH RECTANGULARITY >= 146.5: van(5.0/0.0)

| | SCALED VARIANCE MINOR >= 308.5

| | | DISTANCE CIRCULARITY < 76.5

| | | | SKEWNESS ABOUT MINOR < 10.5

| | | | | MAX.LENGTH RECTANGULARITY < 134.5

| | | | | | KURTOSIS ABOUT MAJOR < 191.0: saab(7.0/0.0)

| | | | | | KURTOSIS ABOUT MAJOR >= 191.0

| | | | | | | PR.AXIS ASPECT RATIO < 63.0

| | | | | | | | CIRCULARITY < 35.5: opel(2.0/0.0)

| | | | | | | | CIRCULARITY >= 35.5: saab(2.0/0.0)

| | | | | | | PR.AXIS ASPECT RATIO >= 63.0: bus(10.0/0.0)

| | | | | MAX.LENGTH RECTANGULARITY >= 134.5: bus(110.0/2.0)

| | | | SKEWNESS ABOUT MINOR >= 10.5

| | | | | PR.AXIS ASPECT RATIO < 62.5

| | | | | | DISTANCE CIRCULARITY < 72.5

| | | | | | | PR.AXIS ASPECT RATIO < 57.0: opel(3.0/1.0)

| | | | | | | PR.AXIS ASPECT RATIO >= 57.0: saab(4.0/0.0)

| | | | | | DISTANCE CIRCULARITY >= 72.5: opel(8.0/1.0)

| | | | | PR.AXIS ASPECT RATIO >= 62.5: bus(3.0/0.0)

| | | DISTANCE CIRCULARITY >= 76.5

| | | | SCATTER RATIO < 148.5

| | | | | CIRCULARITY < 40.5: opel(3.0/0.0)

| | | | | CIRCULARITY >= 40.5: van(3.0/0.0)

| | | | SCATTER RATIO >= 148.5

| | | | | CIRCULARITY < 38.5

| | | | | | MAX.LENGTH RECTANGULARITY < 127.5: opel(5.0/1.0)

| | | | | | MAX.LENGTH RECTANGULARITY >= 127.5: saab(7.0/0.0)

| | | | | CIRCULARITY >= 38.5

| | | | | | MAX.LENGTH RECTANGULARITY < 146.5: opel(9.0/1.0)

| | | | | | MAX.LENGTH RECTANGULARITY >= 146.5: saab(2.0/0.0)

| MAX.LENGTH ASPECT RATIO >= 8.5

| | HOLLOWS RATIO < 189.5: bus(4.0/1.0)

| | HOLLOWS RATIO >= 189.5

| | | SKEWNESS ABOUT MAJOR < 63.5: saab(3.0/1.0)

| | | SKEWNESS ABOUT MAJOR >= 63.5: van(105.0/2.0)

Size of the Tree: 147

Number of Leaf Nodes: 74

Time taken to build model: 0.53 seconds

=== Stratified cross-validation ===

=== Summary ===

Correctly Classified Instances 598 70.6856 %

Incorrectly Classified Instances 248 29.3144 %

Kappa statistic 0.609

Mean absolute error 0.1566

Root mean squared error 0.3483

Relative absolute error 41.768 %

Root relative squared error 80.4525 %

Total Number of Instances 846

=== Detailed Accuracy By Class ===

TP Rate FP Rate Precision Recall F-Measure MCC ROC Area PRC Area Class

0.869 0.059 0.820 0.869 0.844 0.795 0.928 0.792 van

0.548 0.184 0.506 0.548 0.527 0.355 0.725 0.453 saab

0.931 0.030 0.914 0.931 0.923 0.896 0.960 0.893 bus

0.486 0.118 0.579 0.486 0.528 0.391 0.771 0.522 opel

Weighted Avg. 0.707 0.099 0.703 0.707 0.704 0.607 0.845 0.664

=== Confusion Matrix ===

a b c d <-- classified as

173 18 3 5 | a = van

22 119 12 64 | b = saab

3 6 203 6 | c = bus

13 92 4 103 | d = opel

1. **Scheme: weka.classifiers.trees.J48 -C 0.25 -M 2**

Relation: Vehicle Silhouettes

Instances: 846

Attributes: 19

COMPACTNESS

CIRCULARITY

DISTANCE CIRCULARITY

RADIUS RATIO

PR.AXIS ASPECT RATIO

MAX.LENGTH ASPECT RATIO

SCATTER RATIO

ELONGATEDNESS

PR.AXIS RECTANGULARITY

MAX.LENGTH RECTANGULARITY

SCALED VARIANCE MAJOR

SCALED VARIANCE MINOR

SCALED RADIUS OF GYRATION

SKEWNESS ABOUT MAJOR

SKEWNESS ABOUT MINOR

KURTOSIS ABOUT MINOR

KURTOSIS ABOUT MAJOR

HOLLOWS RATIO

CLASS

Test mode: 10-fold cross-validation

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

J48 pruned tree

------------------

ELONGATEDNESS <= 41

| MAX.LENGTH ASPECT RATIO <= 7

| | COMPACTNESS <= 95

| | | PR.AXIS ASPECT RATIO <= 67

| | | | KURTOSIS ABOUT MAJOR <= 196

| | | | | COMPACTNESS <= 89: opel (6.0/1.0)

| | | | | COMPACTNESS > 89

| | | | | | SKEWNESS ABOUT MAJOR <= 72: saab (10.0)

| | | | | | SKEWNESS ABOUT MAJOR > 72: opel (2.0)

| | | | KURTOSIS ABOUT MAJOR > 196: opel (3.0/1.0)

| | | PR.AXIS ASPECT RATIO > 67: bus (16.0)

| | COMPACTNESS > 95: bus (70.0/1.0)

| MAX.LENGTH ASPECT RATIO > 7

| | SCALED VARIANCE MINOR <= 721

| | | HOLLOWS RATIO <= 195

| | | | MAX.LENGTH ASPECT RATIO <= 8

| | | | | ELONGATEDNESS <= 37: opel (2.0)

| | | | | ELONGATEDNESS > 37

| | | | | | DISTANCE CIRCULARITY <= 82: opel (2.0)

| | | | | | DISTANCE CIRCULARITY > 82: saab (6.0/1.0)

| | | | MAX.LENGTH ASPECT RATIO > 8

| | | | | KURTOSIS ABOUT MAJOR <= 185

| | | | | | COMPACTNESS <= 102: opel (4.0)

| | | | | | COMPACTNESS > 102: saab (2.0)

| | | | | KURTOSIS ABOUT MAJOR > 185: opel (23.0)

| | | HOLLOWS RATIO > 195

| | | | COMPACTNESS <= 109

| | | | | SKEWNESS ABOUT MAJOR <= 67

| | | | | | PR.AXIS ASPECT RATIO <= 58: opel (6.0)

| | | | | | PR.AXIS ASPECT RATIO > 58

| | | | | | | SKEWNESS ABOUT MAJOR <= 61: saab (4.0)

| | | | | | | SKEWNESS ABOUT MAJOR > 61

| | | | | | | | HOLLOWS RATIO <= 203

| | | | | | | | | DISTANCE CIRCULARITY <= 78: saab (3.0)

| | | | | | | | | DISTANCE CIRCULARITY > 78

| | | | | | | | | | KURTOSIS ABOUT MINOR <= 16

| | | | | | | | | | | HOLLOWS RATIO <= 198: opel (4.0)

| | | | | | | | | | | HOLLOWS RATIO > 198

| | | | | | | | | | | | PR.AXIS ASPECT RATIO <= 59: opel (3.0)

| | | | | | | | | | | | PR.AXIS ASPECT RATIO > 59

| | | | | | | | | | | | | SKEWNESS ABOUT MAJOR <= 66

| | | | | | | | | | | | | | HOLLOWS RATIO <= 201

| | | | | | | | | | | | | | | MAX.LENGTH ASPECT RATIO <= 9: saab (3.0)

| | | | | | | | | | | | | | | MAX.LENGTH ASPECT RATIO > 9: opel (2.0)

| | | | | | | | | | | | | | HOLLOWS RATIO > 201: opel (3.0)

| | | | | | | | | | | | | SKEWNESS ABOUT MAJOR > 66: saab (8.0/2.0)

| | | | | | | | | | KURTOSIS ABOUT MINOR > 16: opel (12.0)

| | | | | | | | HOLLOWS RATIO > 203

| | | | | | | | | PR.AXIS ASPECT RATIO <= 60: saab (8.0)

| | | | | | | | | PR.AXIS ASPECT RATIO > 60

| | | | | | | | | | KURTOSIS ABOUT MAJOR <= 193: saab (5.0)

| | | | | | | | | | KURTOSIS ABOUT MAJOR > 193

| | | | | | | | | | | PR.AXIS ASPECT RATIO <= 63

| | | | | | | | | | | | KURTOSIS ABOUT MAJOR <= 196

| | | | | | | | | | | | | ELONGATEDNESS <= 33: opel (2.0)

| | | | | | | | | | | | | ELONGATEDNESS > 33: saab (4.0/1.0)

| | | | | | | | | | | | KURTOSIS ABOUT MAJOR > 196: opel (11.0/1.0)

| | | | | | | | | | | PR.AXIS ASPECT RATIO > 63

| | | | | | | | | | | | MAX.LENGTH ASPECT RATIO <= 10: saab (4.0)

| | | | | | | | | | | | MAX.LENGTH ASPECT RATIO > 10: opel (3.0/1.0)

| | | | | SKEWNESS ABOUT MAJOR > 67

| | | | | | COMPACTNESS <= 106

| | | | | | | HOLLOWS RATIO <= 198

| | | | | | | | PR.AXIS RECTANGULARITY <= 24

| | | | | | | | | SKEWNESS ABOUT MAJOR <= 72

| | | | | | | | | | KURTOSIS ABOUT MAJOR <= 187

| | | | | | | | | | | DISTANCE CIRCULARITY <= 98: opel (2.0)

| | | | | | | | | | | DISTANCE CIRCULARITY > 98: saab (7.0)

| | | | | | | | | | KURTOSIS ABOUT MAJOR > 187

| | | | | | | | | | | SCATTER RATIO <= 204

| | | | | | | | | | | | HOLLOWS RATIO <= 197

| | | | | | | | | | | | | MAX.LENGTH ASPECT RATIO <= 9: saab (5.0)

| | | | | | | | | | | | | MAX.LENGTH ASPECT RATIO > 9

| | | | | | | | | | | | | | CIRCULARITY <= 50: opel (4.0)

| | | | | | | | | | | | | | CIRCULARITY > 50: saab (2.0)

| | | | | | | | | | | | HOLLOWS RATIO > 197

| | | | | | | | | | | | | MAX.LENGTH ASPECT RATIO <= 8: opel (2.0)

| | | | | | | | | | | | | MAX.LENGTH ASPECT RATIO > 8

| | | | | | | | | | | | | | RADIUS RATIO <= 193: saab (2.0)

| | | | | | | | | | | | | | RADIUS RATIO > 193: opel (4.0)

| | | | | | | | | | | SCATTER RATIO > 204: opel (9.0)

| | | | | | | | | SKEWNESS ABOUT MAJOR > 72: saab (12.0/1.0)

| | | | | | | | PR.AXIS RECTANGULARITY > 24: opel (7.0)

| | | | | | | HOLLOWS RATIO > 198

| | | | | | | | ELONGATEDNESS <= 34

| | | | | | | | | DISTANCE CIRCULARITY <= 98: opel (3.0)

| | | | | | | | | DISTANCE CIRCULARITY > 98

| | | | | | | | | | COMPACTNESS <= 101

| | | | | | | | | | | SKEWNESS ABOUT MINOR <= 3: saab (3.0)

| | | | | | | | | | | SKEWNESS ABOUT MINOR > 3: opel (4.0)

| | | | | | | | | | COMPACTNESS > 101: saab (15.0)

| | | | | | | | ELONGATEDNESS > 34: saab (7.0)

| | | | | | COMPACTNESS > 106: saab (24.0/1.0)

| | | | COMPACTNESS > 109: saab (16.0)

| | SCALED VARIANCE MINOR > 721: opel (23.0/1.0)

ELONGATEDNESS > 41

| MAX.LENGTH ASPECT RATIO <= 8

| | SCALED VARIANCE MINOR <= 305

| | | COMPACTNESS <= 82

| | | | PR.AXIS RECTANGULARITY <= 18

| | | | | COMPACTNESS <= 81: opel (11.0)

| | | | | COMPACTNESS > 81: saab (5.0/1.0)

| | | | PR.AXIS RECTANGULARITY > 18: saab (2.0)

| | | COMPACTNESS > 82

| | | | MAX.LENGTH RECTANGULARITY <= 138

| | | | | PR.AXIS RECTANGULARITY <= 17

| | | | | | SKEWNESS ABOUT MINOR <= 18

| | | | | | | ELONGATEDNESS <= 58: van (30.0/3.0)

| | | | | | | ELONGATEDNESS > 58: saab (3.0)

| | | | | | SKEWNESS ABOUT MINOR > 18: opel (3.0/1.0)

| | | | | PR.AXIS RECTANGULARITY > 17

| | | | | | PR.AXIS RECTANGULARITY <= 18

| | | | | | | MAX.LENGTH RECTANGULARITY <= 128

| | | | | | | | HOLLOWS RATIO <= 186: saab (6.0)

| | | | | | | | HOLLOWS RATIO > 186

| | | | | | | | | SCALED VARIANCE MAJOR <= 164

| | | | | | | | | | MAX.LENGTH RECTANGULARITY <= 124

| | | | | | | | | | | KURTOSIS ABOUT MINOR <= 27: saab (2.0)

| | | | | | | | | | | KURTOSIS ABOUT MINOR > 27: opel (3.0)

| | | | | | | | | | MAX.LENGTH RECTANGULARITY > 124: opel (6.0)

| | | | | | | | | SCALED VARIANCE MAJOR > 164: saab (2.0)

| | | | | | | MAX.LENGTH RECTANGULARITY > 128

| | | | | | | | SCALED RADIUS OF GYRATION <= 138: van (19.0/2.0)

| | | | | | | | SCALED RADIUS OF GYRATION > 138

| | | | | | | | | PR.AXIS ASPECT RATIO <= 53: van (2.0)

| | | | | | | | | PR.AXIS ASPECT RATIO > 53

| | | | | | | | | | MAX.LENGTH ASPECT RATIO <= 5

| | | | | | | | | | | COMPACTNESS <= 84: opel (2.0)

| | | | | | | | | | | COMPACTNESS > 84: saab (4.0)

| | | | | | | | | | MAX.LENGTH ASPECT RATIO > 5

| | | | | | | | | | | DISTANCE CIRCULARITY <= 66

| | | | | | | | | | | | SKEWNESS ABOUT MINOR <= 4: opel (2.0)

| | | | | | | | | | | | SKEWNESS ABOUT MINOR > 4: saab (2.0)

| | | | | | | | | | | DISTANCE CIRCULARITY > 66: opel (5.0)

| | | | | | PR.AXIS RECTANGULARITY > 18: saab (3.0)

| | | | MAX.LENGTH RECTANGULARITY > 138

| | | | | ELONGATEDNESS <= 47

| | | | | | MAX.LENGTH RECTANGULARITY <= 143: saab (3.0/1.0)

| | | | | | MAX.LENGTH RECTANGULARITY > 143: van (4.0)

| | | | | ELONGATEDNESS > 47: van (39.0/1.0)

| | SCALED VARIANCE MINOR > 305

| | | DISTANCE CIRCULARITY <= 76

| | | | SKEWNESS ABOUT MINOR <= 10

| | | | | SKEWNESS ABOUT MAJOR <= 64

| | | | | | CIRCULARITY <= 35: opel (2.0)

| | | | | | CIRCULARITY > 35: saab (2.0)

| | | | | SKEWNESS ABOUT MAJOR > 64

| | | | | | SCATTER RATIO <= 143

| | | | | | | DISTANCE CIRCULARITY <= 70: bus (4.0)

| | | | | | | DISTANCE CIRCULARITY > 70: van (2.0)

| | | | | | SCATTER RATIO > 143

| | | | | | | CIRCULARITY <= 41

| | | | | | | | PR.AXIS ASPECT RATIO <= 62: saab (7.0)

| | | | | | | | PR.AXIS ASPECT RATIO > 62

| | | | | | | | | SCALED VARIANCE MAJOR <= 180: bus (19.0)

| | | | | | | | | SCALED VARIANCE MAJOR > 180

| | | | | | | | | | DISTANCE CIRCULARITY <= 74: saab (2.0)

| | | | | | | | | | DISTANCE CIRCULARITY > 74: bus (2.0)

| | | | | | | CIRCULARITY > 41: bus (97.0)

| | | | SKEWNESS ABOUT MINOR > 10

| | | | | PR.AXIS ASPECT RATIO <= 62

| | | | | | PR.AXIS RECTANGULARITY <= 19

| | | | | | | ELONGATEDNESS <= 43: saab (2.0)

| | | | | | | ELONGATEDNESS > 43

| | | | | | | | SCALED VARIANCE MAJOR <= 165: saab (2.0)

| | | | | | | | SCALED VARIANCE MAJOR > 165

| | | | | | | | | CIRCULARITY <= 42: opel (7.0)

| | | | | | | | | CIRCULARITY > 42

| | | | | | | | | | RADIUS RATIO <= 151: saab (2.0)

| | | | | | | | | | RADIUS RATIO > 151: opel (2.0)

| | | | | | PR.AXIS RECTANGULARITY > 19: opel (2.0)

| | | | | PR.AXIS ASPECT RATIO > 62: bus (3.0)

| | | DISTANCE CIRCULARITY > 76

| | | | PR.AXIS ASPECT RATIO <= 61

| | | | | PR.AXIS RECTANGULARITY <= 19

| | | | | | SCALED RADIUS OF GYRATION <= 132: saab (3.0)

| | | | | | SCALED RADIUS OF GYRATION > 132

| | | | | | | MAX.LENGTH RECTANGULARITY <= 145

| | | | | | | | HOLLOWS RATIO <= 192

| | | | | | | | | SKEWNESS ABOUT MINOR <= 8: saab (3.0)

| | | | | | | | | SKEWNESS ABOUT MINOR > 8: opel (4.0)

| | | | | | | | HOLLOWS RATIO > 192: opel (10.0)

| | | | | | | MAX.LENGTH RECTANGULARITY > 145: saab (2.0)

| | | | | PR.AXIS RECTANGULARITY > 19: saab (3.0/1.0)

| | | | PR.AXIS ASPECT RATIO > 61

| | | | | SKEWNESS ABOUT MINOR <= 5

| | | | | | CIRCULARITY <= 38: opel (2.0)

| | | | | | CIRCULARITY > 38: van (3.0)

| | | | | SKEWNESS ABOUT MINOR > 5: saab (3.0)

| MAX.LENGTH ASPECT RATIO > 8

| | HOLLOWS RATIO <= 189: bus (5.0/1.0)

| | HOLLOWS RATIO > 189

| | | SKEWNESS ABOUT MAJOR <= 63: saab (4.0/1.0)

| | | SKEWNESS ABOUT MAJOR > 63: van (107.0/2.0)

Number of Leaves : 98

Size of the tree : 195

Time taken to build model: 0.1 seconds

=== Stratified cross-validation ===

=== Summary ===

Correctly Classified Instances 614 72.5768 %

Incorrectly Classified Instances 232 27.4232 %

Kappa statistic 0.6343

Mean absolute error 0.1415

Root mean squared error 0.3355

Relative absolute error 37.7493 %

Root relative squared error 77.4887 %

Total Number of Instances 846

=== Detailed Accuracy By Class ===

TP Rate FP Rate Precision Recall F-Measure MCC ROC Area PRC Area Class

0.894 0.040 0.873 0.894 0.883 0.847 0.932 0.793 van

0.461 0.141 0.529 0.461 0.493 0.335 0.758 0.473 saab

0.950 0.024 0.932 0.950 0.941 0.920 0.977 0.945 bus

0.608 0.161 0.558 0.608 0.582 0.435 0.784 0.544 opel

Weighted Avg. 0.726 0.092 0.721 0.726 0.723 0.631 0.862 0.687

=== Confusion Matrix ===

a b c d <-- classified as

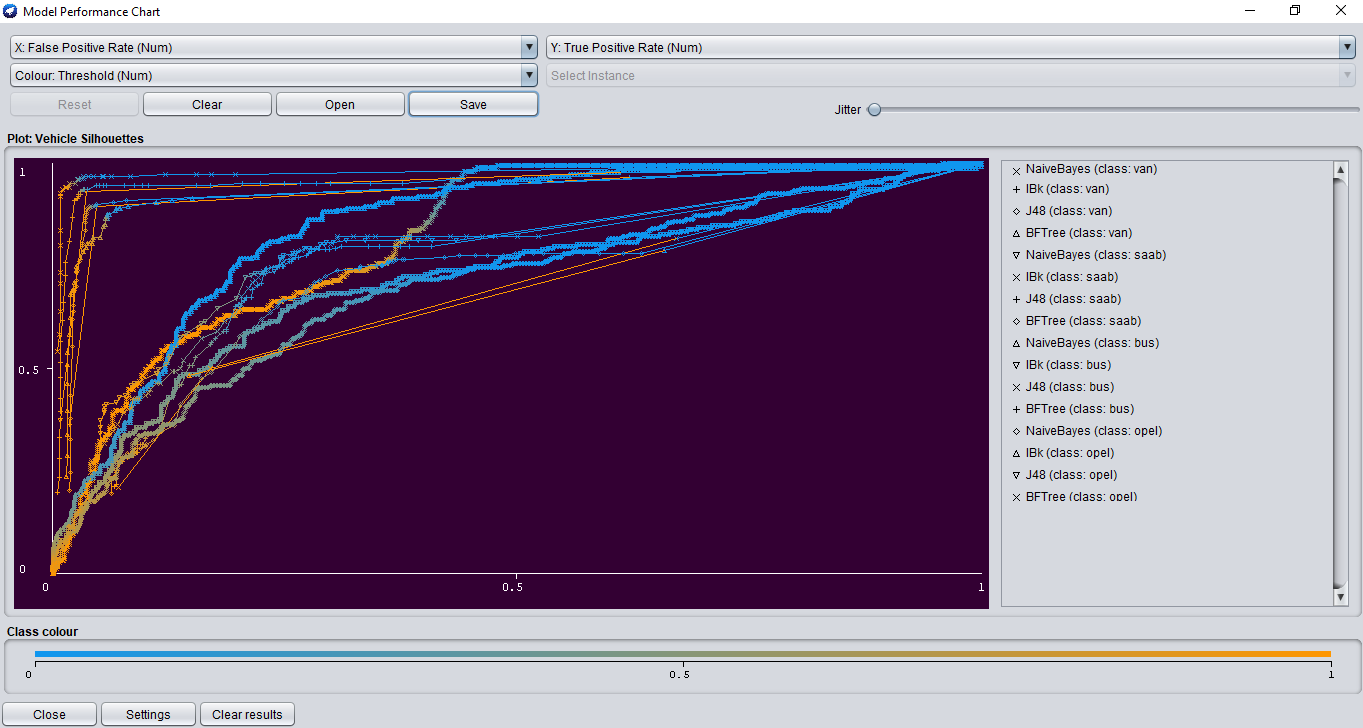
178 11 6 4 | a = van

16 100 6 95 | b = saab

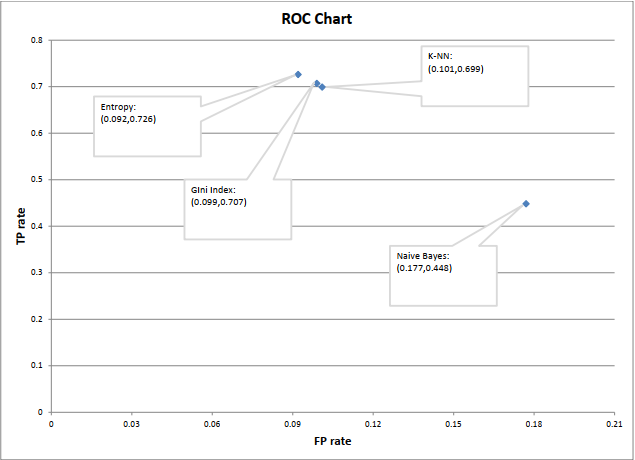
4 4 207 3 | c = bus

6 74 3 129 | d = opel

**ROC Curve on Weka:**



**ROC Curve on Excel:**



**Analysis & Result:**

Analyzing all 4 different algorithms for the given specification & data set was tested, it was seen **J48** as a best classifier for the case. According to analysis, **J48** has the highest correctly classified instances. Correctly classified instances are **614** which is = **72.5768 %** & incorrectly classified instances are **232** which is = **27.4232 %**.

Now, 2nd nearest best algorithm is **BFTree**. Correctly classified instances are **598** which is = **70.6856 %** & incorrectly classified instances are **248** which is = **29.3144 %**.

* **Distance Measure:**

I have used Euclidean Distance Formula to measure the distance to compare which algorithm gives the best result. Considering best possible classifier (0,1).

Formula: √ ((FP) ^2 + (TP-1) ^2)

For Naive Bayes : TP = 0.448, FP = 0.177, Distance = 0.579

For Lazy.ibk : TP = 0.699, FP = 0.101, Distance = 0.317

For BFTree : TP = 0.707, FP = 0.099, Distance = 0.309

For J48 : TP = 0.726, FP = 0.092, Distance = 0.289

Even in the ROC Curve, the **J48** is the nearest to the best possible point (1). So, **J48** can be chosen as the best classifier because other of the three classifiers points are comparatively away from the best point. From other point of view, rest of the three classifiers belongs to the worst triangle and only **J48** belong to the best triangle and it is also adjacent to the best point. So, to choose the best classifier from these two, distance measurement is needed and the formula is: √ ((FP) ^2 + (TP-1) ^2).

For **J48**, the distance is the nearest to the best possible point in the ROC Curve. So, for this dataset **J48** is the best classifier.