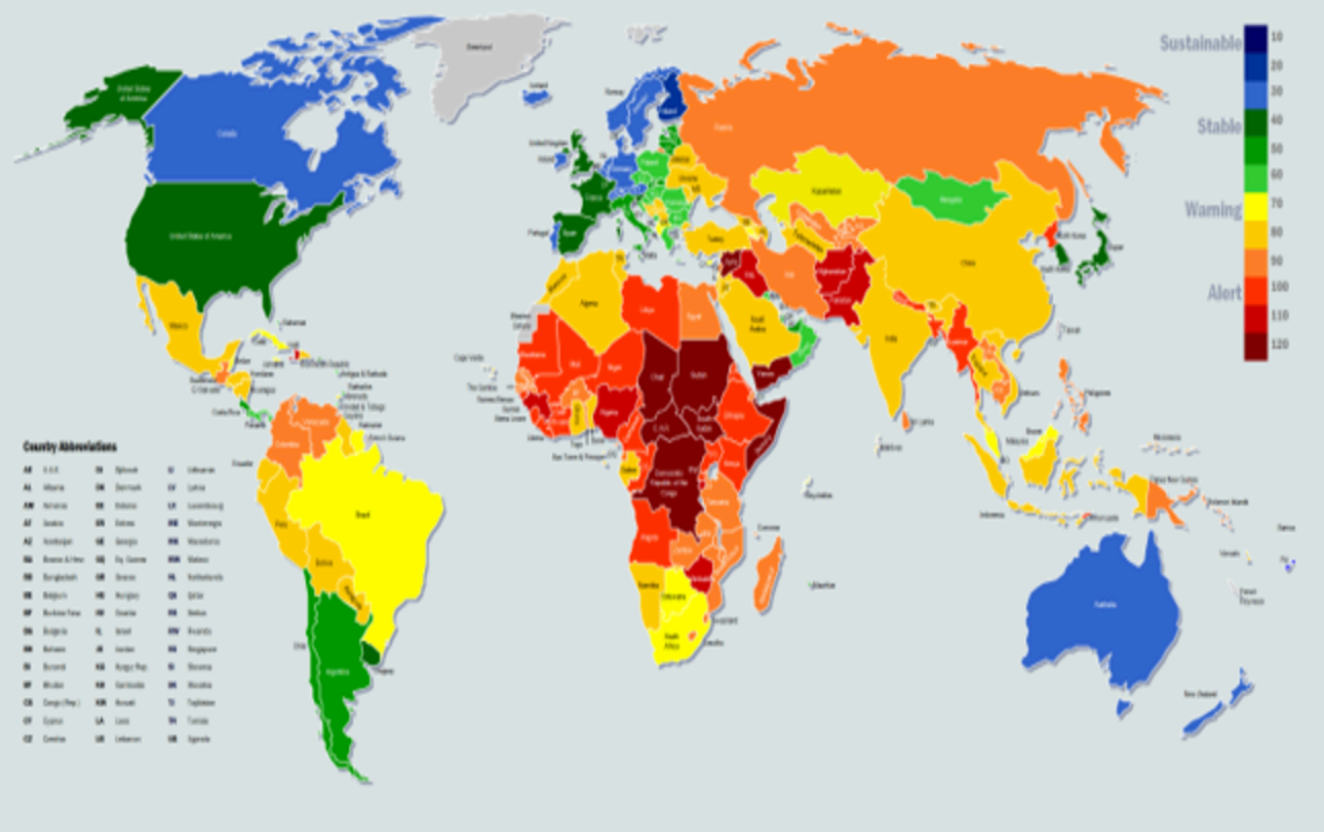
ITCS 6162: Knowledge Discovery in Databases
Project Report



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Dataset

Data for the years 2011-2014 is collected from the URL: http://fsi.fundforpeace.org/

Tools Used

Java Compiler
WEKA 3.6 (stable version)

Data Extraction

We have used web sources like Wikipedia and annually published global reports to extract values for few new attributes to consolidate with the data set.

WEKA

Weka is an open source and popular suite of machine learning workbench that contains a collection of visualization tools and algorithms for data analysis and predictive modeling, together with graphical user interfaces for easy access to this functionality. The original non-Java version of Weka was a TCL/TK front-end to (mostly third-party) modeling algorithms implemented in other programming languages, plus data preprocessing utilities in C, and a Make file-based system for running machine learning experiments. This original version was primarily designed as a tool for analyzing data from agricultural domains but the more recent fully Java-based version (Weka 3), is now used in many different application areas, in particular for educational purposes and research.

Weka supports several standard data mining tasks, more specifically, data preprocessing, clustering, classification, regression, visualization, and feature selection. All of Weka's techniques are predicated on the assumption that the data is available as a single flat file or relation, where each data point is described by a fixed number of attributes (normally, numeric or nominal attributes, but some other attribute types are also supported). Weka provides access to SQL databases using Java Database Connectivity and can process the result returned by a database query. It is not capable of multi-relational data mining, but there is separate software for converting a collection of linked database tables into a single table that is suitable for processing using Weka. Another important area that is currently not covered by the algorithms included in the Weka distribution is sequence modeling.

Work Flow

Extraction of Structured Dataset and Pre-Processing

- ✓ We have extracted data for 178 countries from the web data. The extracted data set is cleaned and refined by replacing undefined values and records having any special characters with 0.
- ✓ The final data set contains 178 countries. The first 12 features (Demographic Pressures, Refugees and IDPs, Group Grievance, Human Flight, Uneven Development, Poverty and Economic Decline, Legitimacy of the State, Public Services, Human Rights, Security Apparatus, Factionalized Elites, External Intervention) are mandatory for the project, the other 6 features (Air Quality Index, Happiness Index, Global Warming Index, Global Peace Index, Technology Usage Index, Global Slavery Index) are the additional features added.
- ✓ Once the data is clean, it is loaded into WEKA Explorer.

Year 2011

Discretize

We have Total as the decision feature. In the data set, the total column is sorted. Since we have to split the total into 4 intervals, we can split it as the levels Alert, Warning, Stable and Sustainable. We need to choose the split to get a maximum entropy gain for the decision feature considered.

Alert 38 Warning 83 Stable 33 Sustainable 23

Entropy Gain for Total

$E(D) = -(((38/177) * \log_4(38/177)) + ((83/177) * \log_4(83/177)) + ((33/177) * \log_4(33/177)) + ((23/177) * \log_4(23/177)))$

$E(D) = -(0.214689266*(-1.109839018) + 0.468926554*(-0.546283059) + 0.186440678*(-1.211605715) + 0.129943503*(-1.472021797))$

$E(D) = 0.911609416$

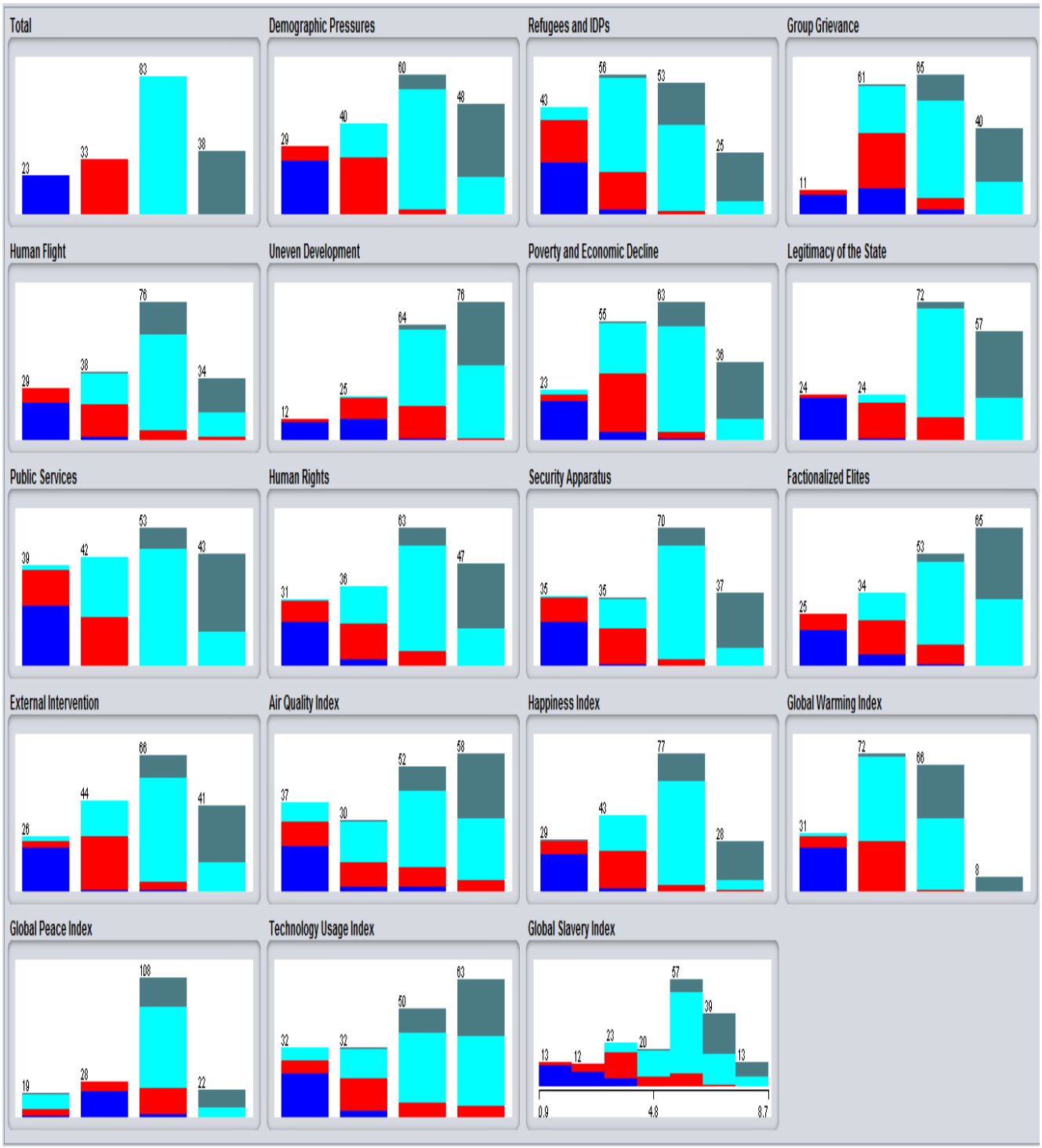
We have calculated the initial entropy and made the split based on the entropy gain of the split. We have chosen the split which has higher Entropy Gain and decided to have the total split into 4 intervals as below

(126.6 … +infinity) (94.1 … 126.6] (61.6 … 94.1] (-infinity … 61.6]

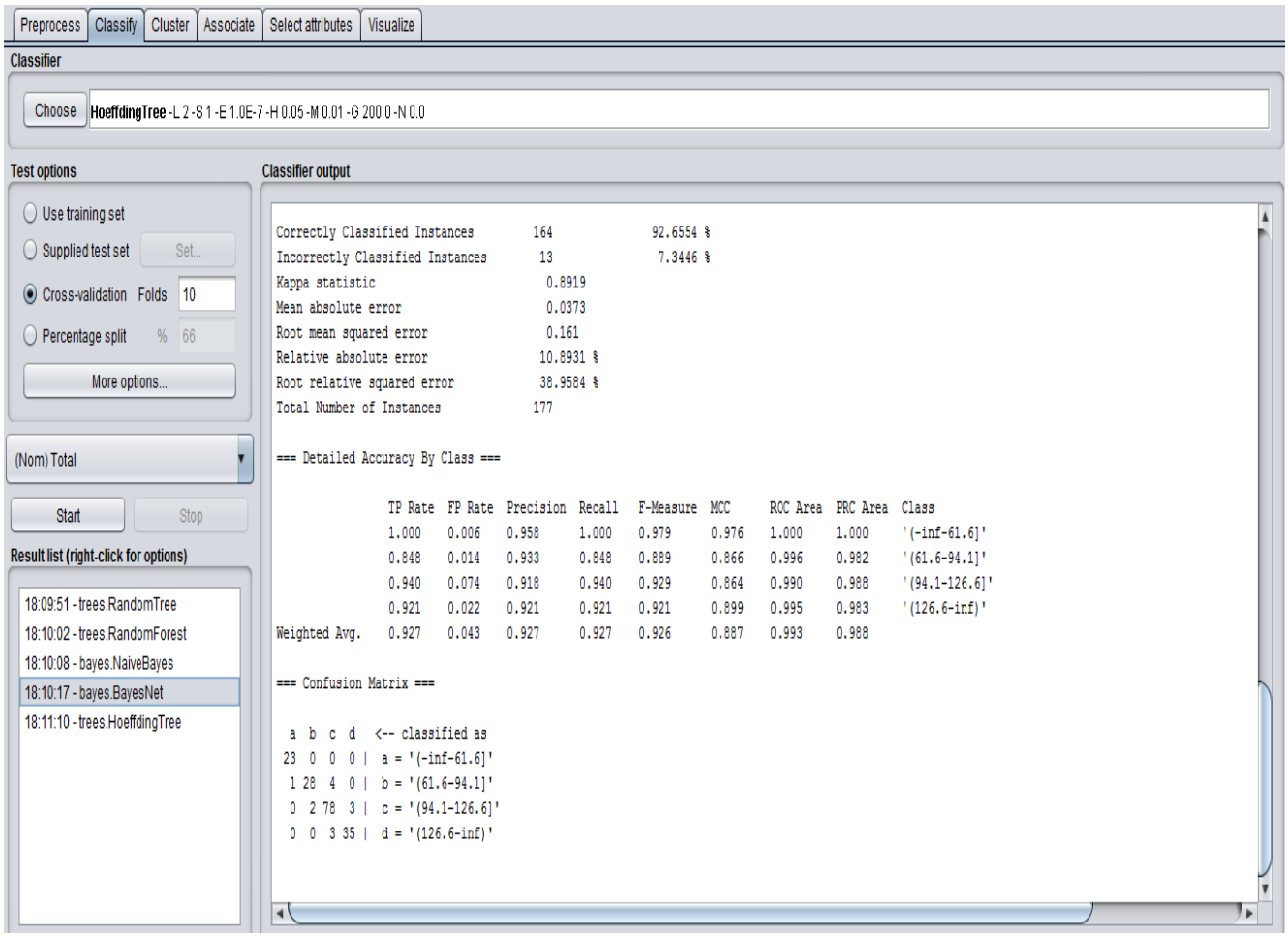
Classification using WEKA

Select Total as the decision feature and apply different algorithms to compare the results and choose the algorithm that gives the best number of correctly classified records.

Visualize all the features



Bayes - BayesNet Classifier



Classifier Output

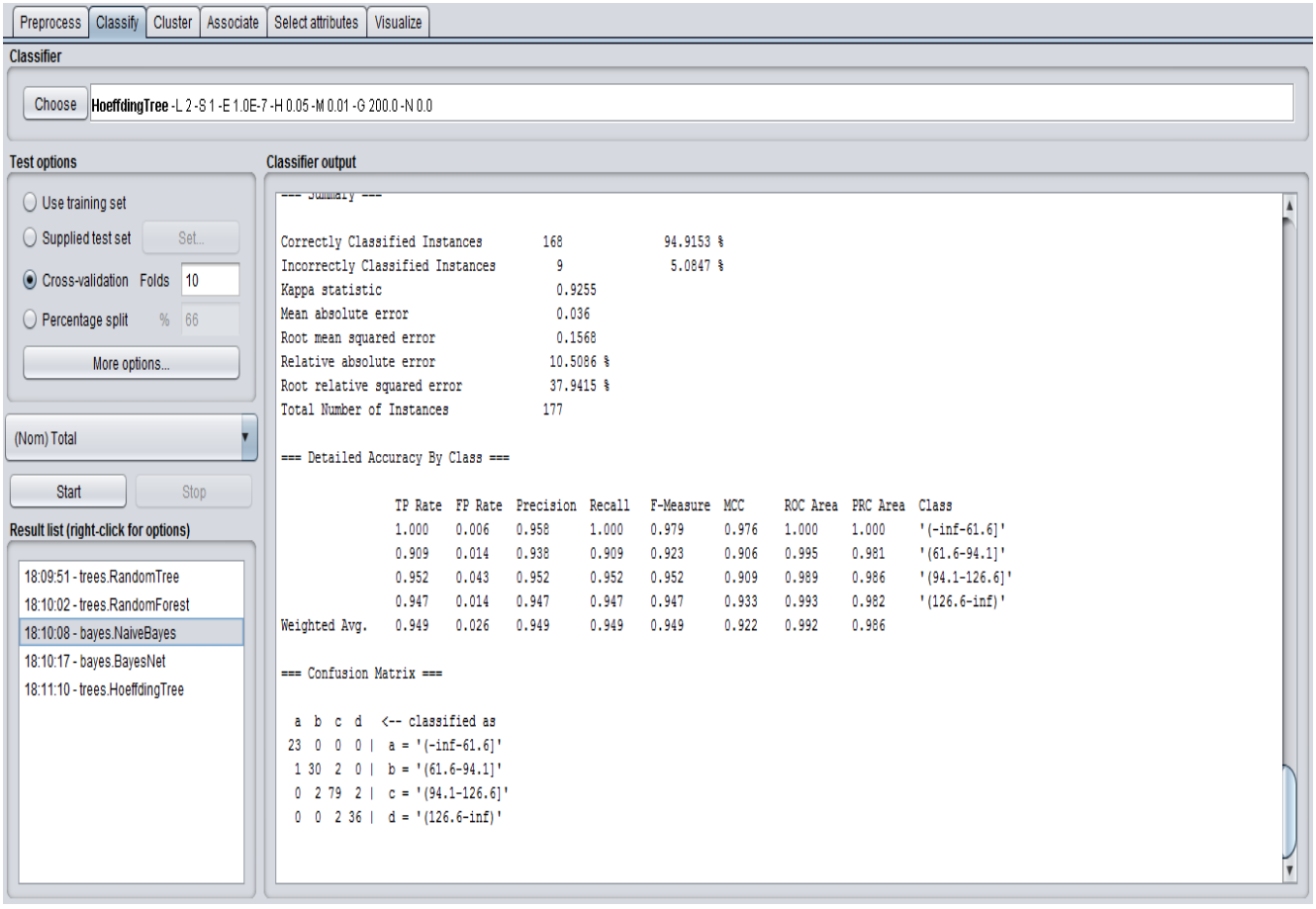
Correctly Classified Instances	164	92.6554 %
Incorrectly Classified Instances	13	7.3446 %
Kappa statistic	0.8919	
Mean absolute error	0.0373	
Root mean squared error	0.161	
Relative absolute error	10.8931 %	
Root relative squared error	38.9584 %	
Total Number of Instances	177	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
1.000	0.006	0.958	1.000	0.979	0.976	1.000	1.000	'(-inf-61.6]'
0.848	0.014	0.933	0.848	0.889	0.866	0.996	0.982	'(61.6-94.1]'
0.940	0.074	0.918	0.940	0.929	0.864	0.990	0.988	'(94.1-126.6]'
0.921	0.022	0.921	0.921	0.921	0.899	0.995	0.983	'(126.6-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \\ \begin{bmatrix} 23 & 0 & 0 & 0 \\ 1 & 28 & 4 & 0 \\ 0 & 2 & 78 & 3 \\ 0 & 0 & 3 & 35 \end{bmatrix} \end{matrix} \quad \begin{matrix} a = '(-\inf - 61.6]' \\ b = '(61.6 - 94.1]' \\ c = '(94.1 - 126.6]' \\ d = '(126.6 - \inf)' \end{matrix}$$

Bayes - Naive Bayes Classifier



Classifier Output

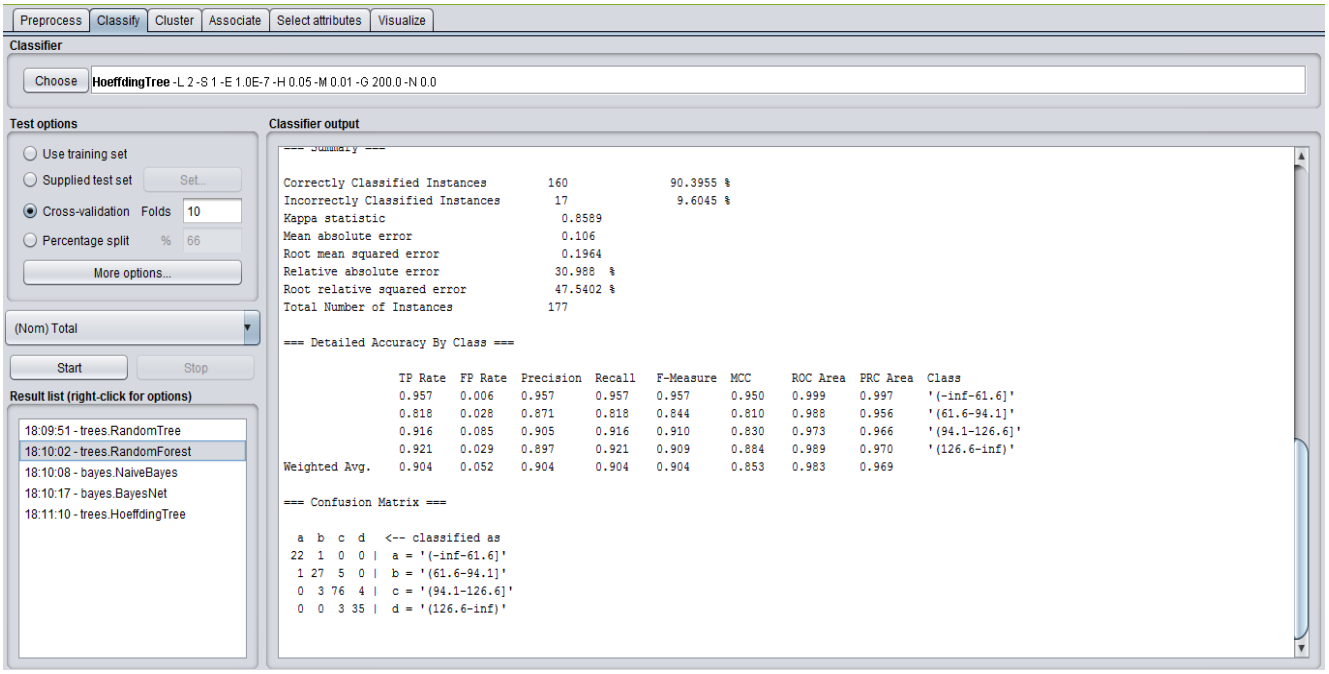
Correctly Classified Instances	168	94.9153 %
Incorrectly Classified Instances	9	5.0847 %
Kappa statistic	0.9255	
Mean absolute error	0.036	
Root mean squared error	0.1568	
Relative absolute error	10.5086 %	
Root relative squared error	37.9415 %	
Total Number of Instances	177	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
1.000	0.006	0.958	1.000	0.979	0.976	1.000	1.000	'(-inf-61.6]'
0.909	0.014	0.938	0.909	0.923	0.906	0.995	0.981	'(61.6-94.1]'
0.952	0.043	0.952	0.952	0.952	0.909	0.989	0.986	'(94.1-126.6]'
0.947	0.014	0.947	0.947	0.947	0.933	0.993	0.982	'(126.6-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 23 & 0 & 0 & 0 \\ 1 & 30 & 2 & 0 \\ 0 & 2 & 79 & 2 \\ 0 & 0 & 2 & 36 \end{bmatrix}$$
$$a = '(-\inf - 61.6]'$$
$$b = '(61.6 - 94.1]'$$
$$c = '(94.1 - 126.6]'$$
$$d = '(126.6 - \inf)'$$

Trees - Random Forest Classifier



Classifier Output

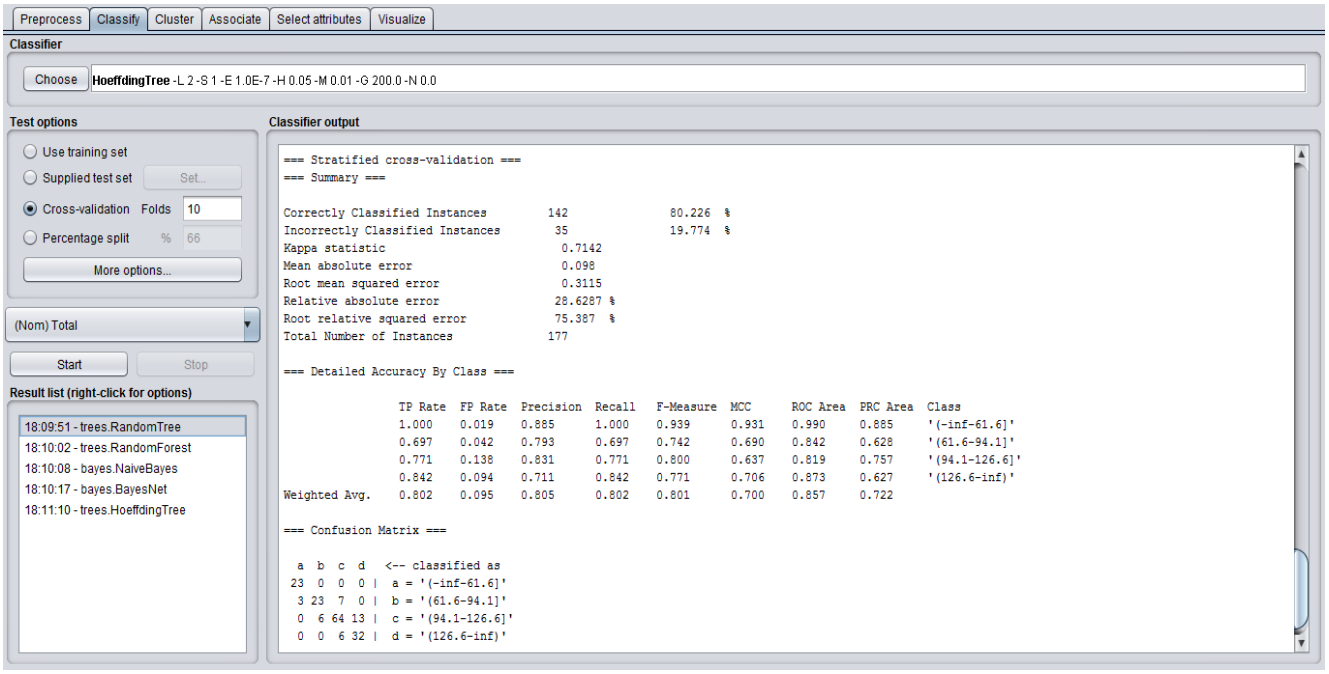
Correctly Classified Instances	160	90.3955 %
Incorrectly Classified Instances	17	9.6045 %
Kappa statistic	0.8589	
Mean absolute error	0.106	
Root mean squared error	0.1964	
Relative absolute error	30.988 %	
Root relative squared error	47.5402 %	
Total Number of Instances	177	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.957	0.006	0.957	0.957	0.957	0.950	0.999	0.997	'(-inf-61.6]'
0.818	0.028	0.871	0.818	0.844	0.810	0.988	0.956	'(61.6-94.1]'
0.916	0.085	0.905	0.916	0.910	0.830	0.973	0.966	'(94.1-126.6]'
0.921	0.029	0.897	0.921	0.909	0.884	0.989	0.970	'(126.6-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 22 & 1 & 0 & 0 \\ 1 & 27 & 5 & 0 \\ 0 & 3 & 76 & 4 \\ 0 & 0 & 3 & 35 \end{bmatrix}$$
$$\begin{aligned} a &= '(-\inf - 61.6]' \\ b &= '(61.6 - 94.1]' \\ c &= '(94.1 - 126.6]' \\ d &= '(126.6 - \inf)' \end{aligned}$$

Trees - Random Tree Classifier



Classifier Output

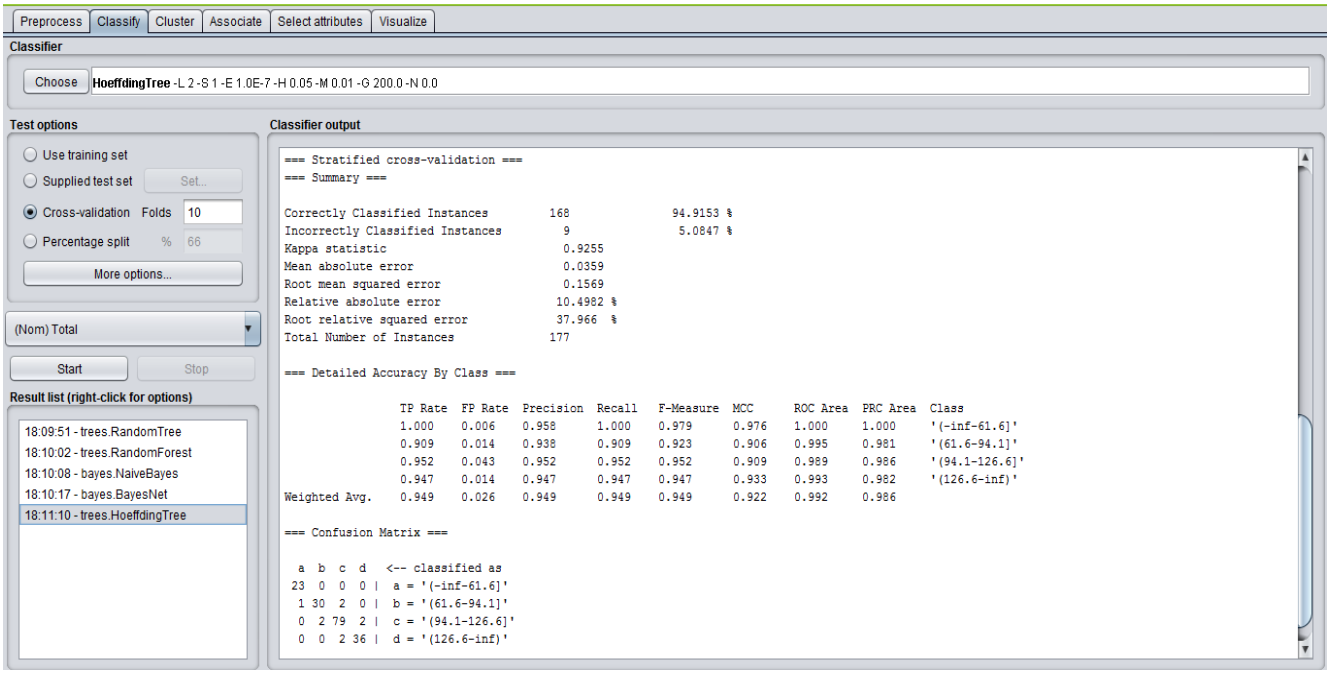
Correctly Classified Instances	142	80.226 %
Incorrectly Classified Instances	35	19.774 %
Kappa statistic	0.7142	
Mean absolute error	0.098	
Root mean squared error	0.3115	
Relative absolute error	18.6287 %	
Root relative squared error	75.387 %	
Total Number of Instances	177	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
1.000	0.019	0.885	1.000	0.939	0.931	0.990	0.885	'(-inf-61.6]'
0.697	0.042	0.793	0.697	0.742	0.690	0.842	0.628	'(61.6-94.1]'
0.771	0.138	0.831	0.771	0.800	0.637	0.819	0.757	'(94.1-126.6]'
0.842	0.094	0.711	0.842	0.771	0.706	0.873	0.627	'(126.6-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 23 & 0 & 0 & 0 \\ 3 & 23 & 7 & 0 \\ 0 & 6 & 64 & 13 \\ 0 & 0 & 6 & 32 \end{bmatrix}$$
$$a = '(-\inf - 61.6]'$$
$$b = '(61.6 - 94.1]'$$
$$c = '(94.1 - 126.6]'$$
$$d = '(126.6 - \inf)'$$

Trees – Hoeffding Tree Classifier



Classifier Output

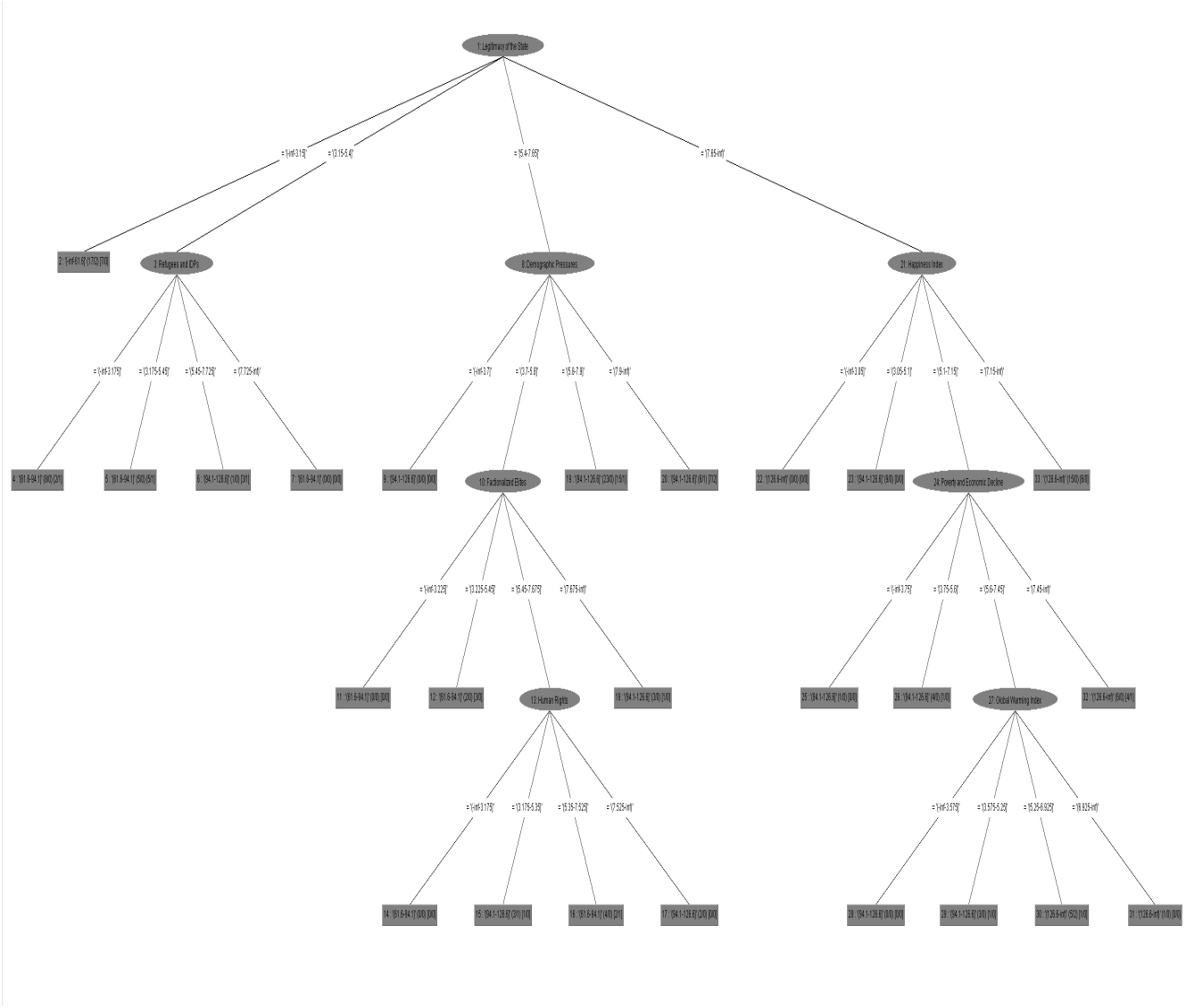
Correctly Classified Instances	168	94.9153 %
Incorrectly Classified Instances	9	5.0847 %
Kappa statistic	0.9255	
Mean absolute error	0.0359	
Root mean squared error	0.1569	
Relative absolute error	10.4982 %	
Root relative squared error	37.966 %	
Total Number of Instances	177	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
1.000	0.006	0.958	1.000	0.979	0.976	1.000	1.000	'(-inf-61.6]'
0.909	0.014	0.938	0.909	0.923	0.906	0.995	0.981	'(61.6-94.1]'
0.952	0.043	0.952	0.952	0.952	0.909	0.989	0.986	'(94.1-126.6]'
0.947	0.014	0.947	0.947	0.947	0.933	0.993	0.982	'(126.6-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 23 & 0 & 0 & 0 \\ 1 & 30 & 2 & 0 \\ 0 & 2 & 79 & 2 \\ 0 & 0 & 2 & 36 \end{bmatrix}$$
$$a = '(-\inf - 61.6]'$$
$$b = '(61.6 - 94.1]'$$
$$c = '(94.1 - 126.6]'$$
$$d = '(126.6 - \inf)'$$

Tree Visualizer

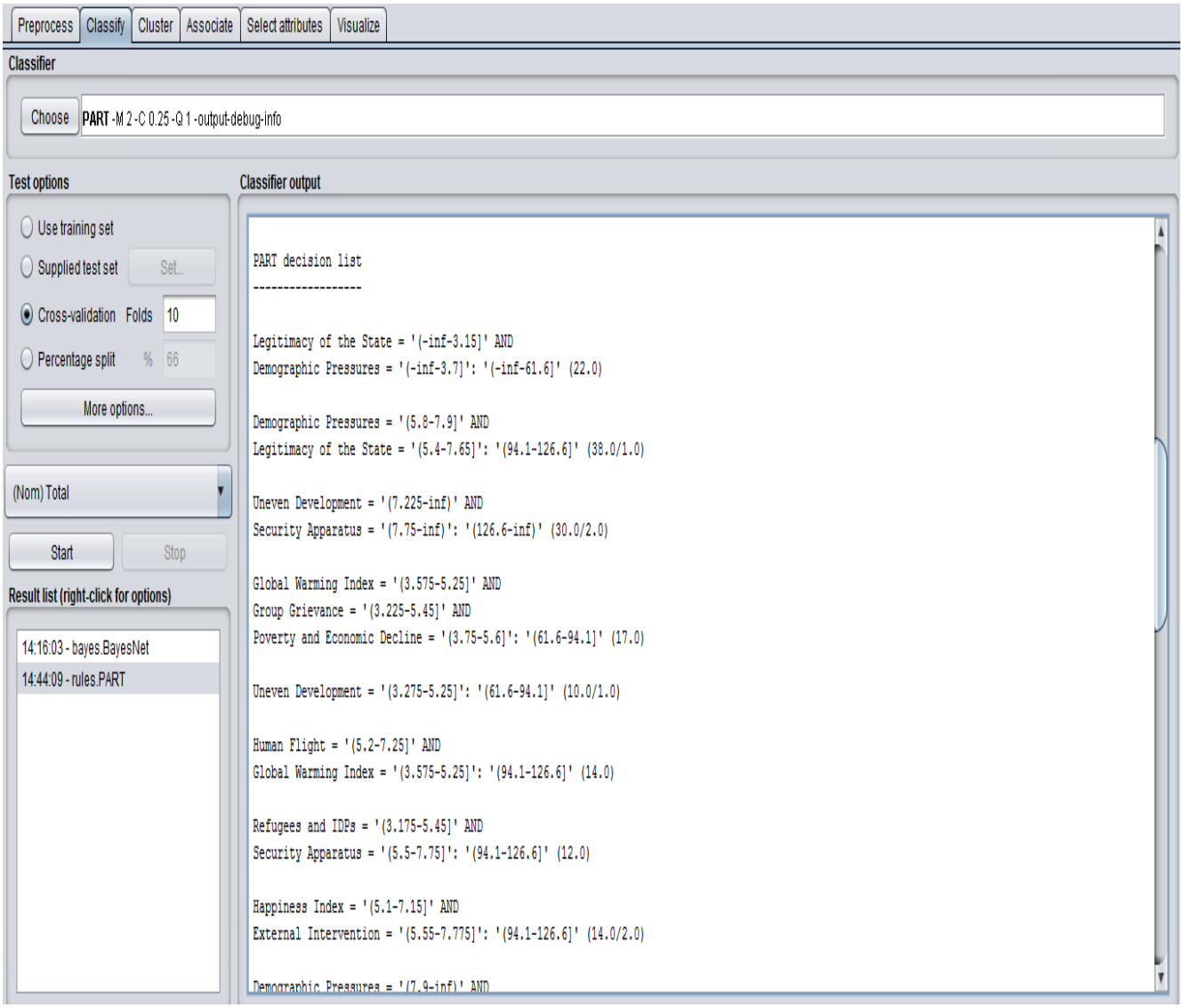


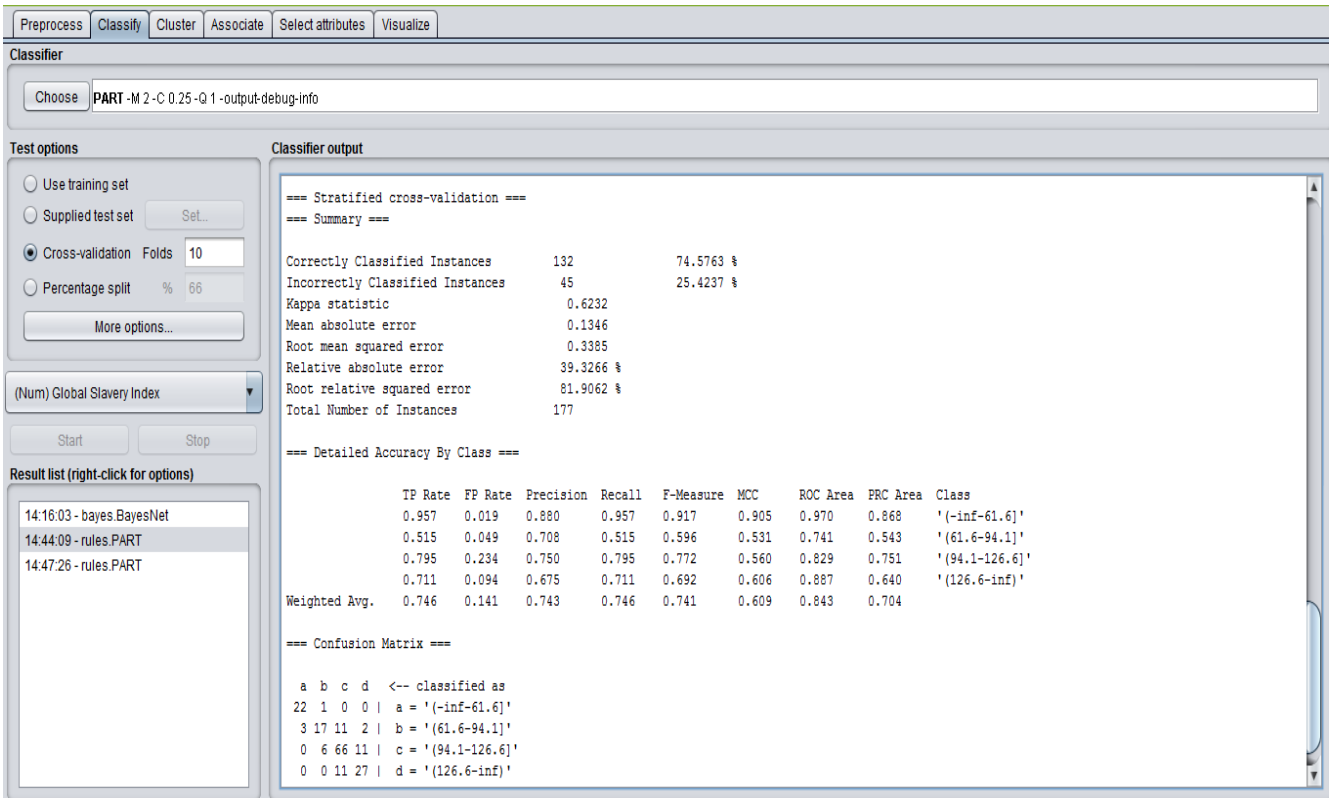
Comparison of Algorithms and Result

Since the percentage of correctly classified instances for Bayes Net, Naïve Bayes, Random Forest, Random Tree and Hoeffding Tree algorithms is 92.6554, 94.9153, 90.3955, 80.226 and 94.9153 respectively. This clearly shows that Naïve Bayes and Hoeffding Tree algorithms are best used to classify as it has high accuracy when compared with other algorithms.

Determining Action Rules

We have determined the action rules by using Weka by selecting the Rules-PART filter as the classifier and run for the data with total as the decision attribute. The rules are logged in a word document and the result screenshot is shown below.





Year 2012

Discretize

We have Total as the decision feature. In the data set, the total column is sorted. Since we have to split the total into 4 intervals, we can split it as the levels Alert, Warning, Stable and Sustainable. We need to choose the split to get a maximum entropy gain for the decision feature considered.

Alert 33 Warning 80 Stable 41 Sustainable 24

Entropy Gain for Total

$E(D) = -(((33/178) * \log_4(33/178)) + ((80/178) * \log_4(80/178)) + ((41/178) * \log_4(41/178)) + ((24/178) * \log_4(24/178)))$

$E(D) = -(0.185393258*(-1.215669656) + 0.449438202*(-0.576902668) + 0.230337079*(-1.059090713) + 0.134831461*(-1.445385465))$

$E(D) = 0.923490351$

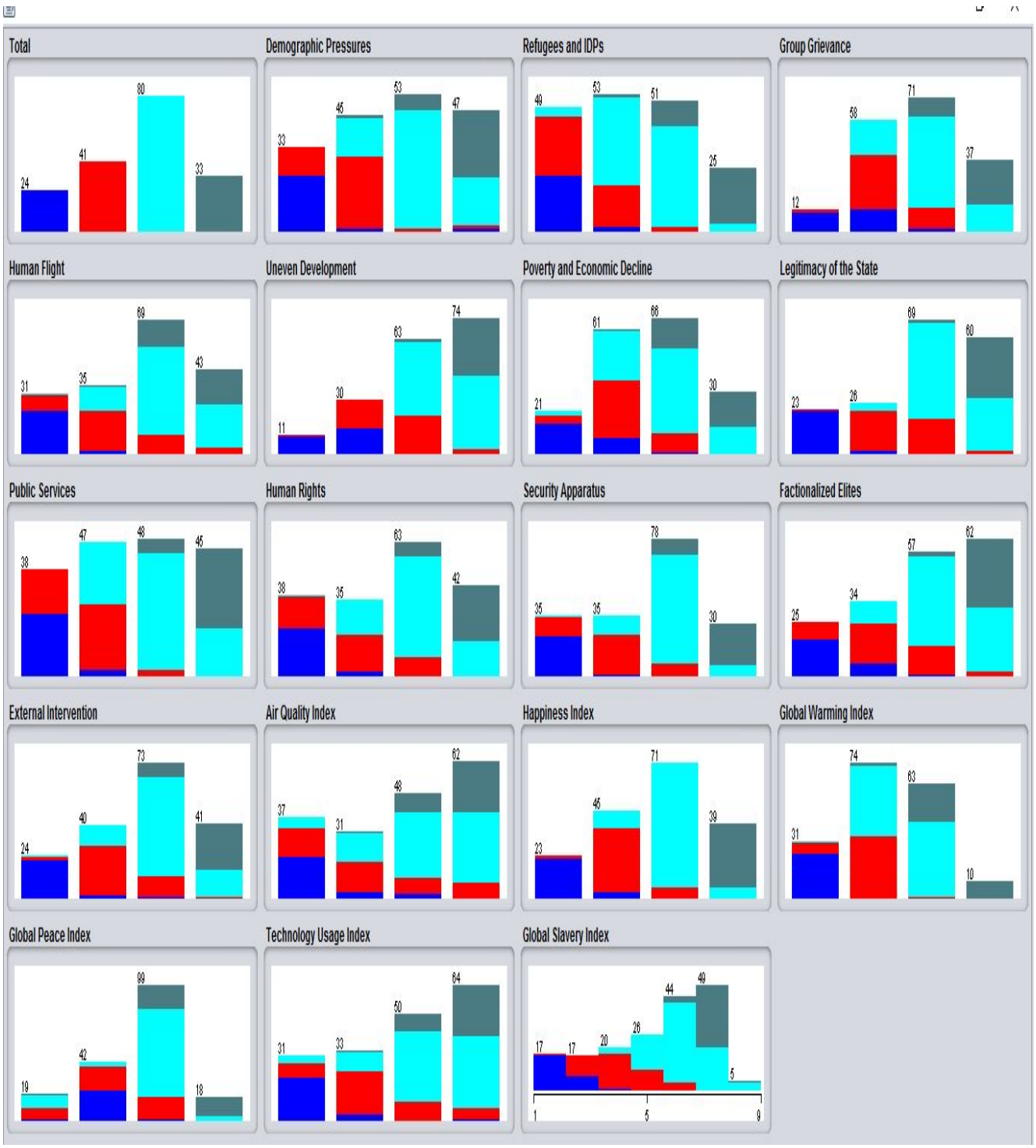
We have calculated the initial entropy and made the split based on the entropy gain of the split. We have chosen the split which has higher Entropy Gain and decided to have the total split into 4 intervals as below

(131.775 … +infinity) (97.65 … 131.775] (63.525 … 97.65] (-infinity … 63.525]

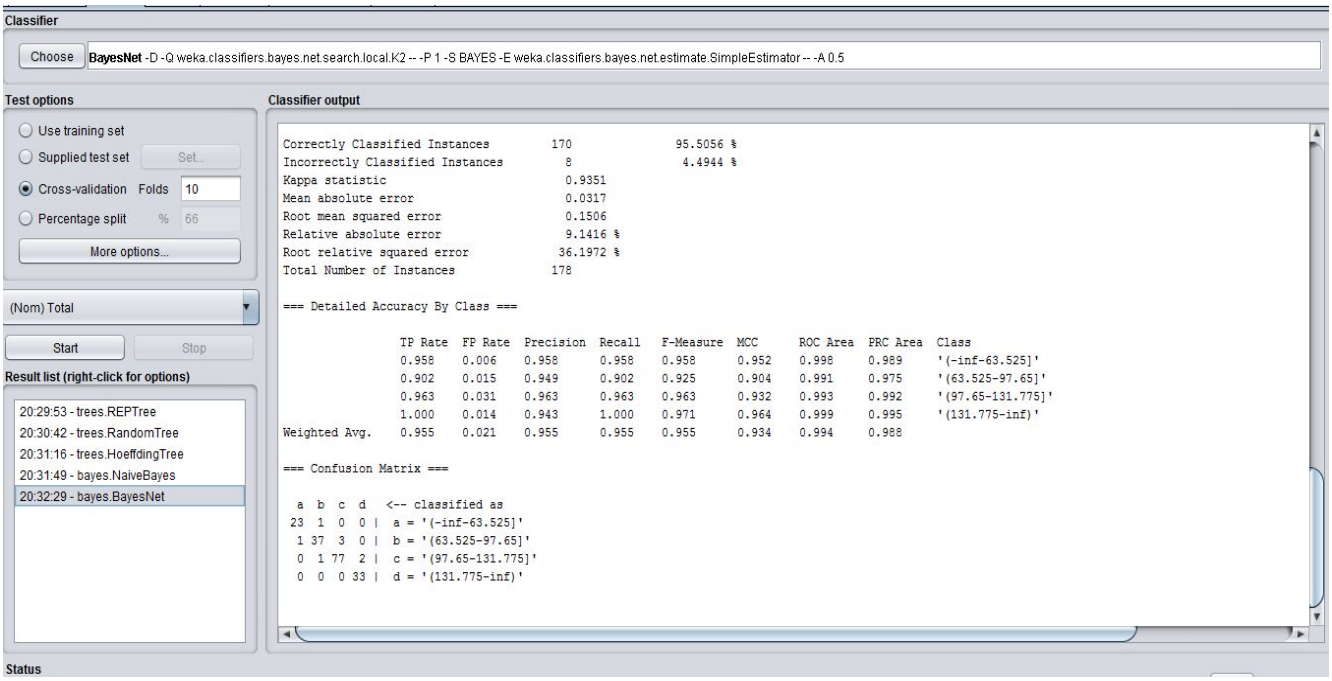
Classification using WEKA

Select Total as the decision feature and apply different algorithms to compare the results and choose the algorithm that gives the best number of correctly classified records.

Visualize all the features



Bayes - BayesNet Classifier



Classifier Output

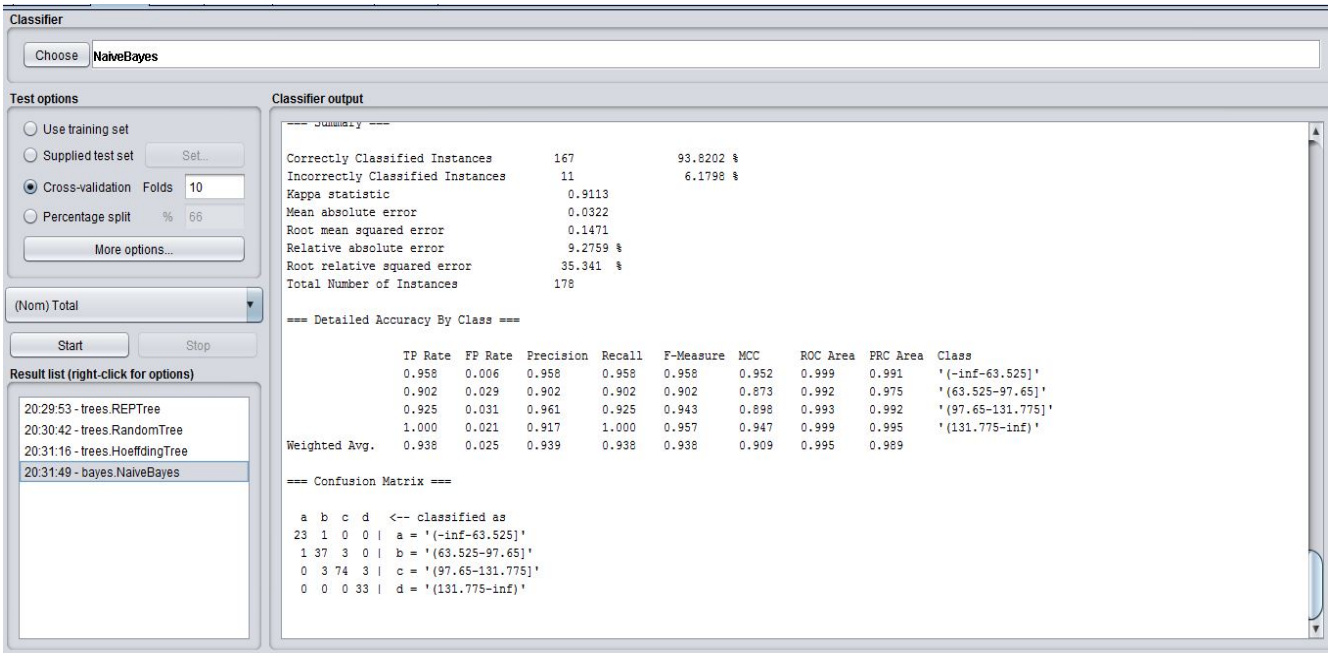
Correctly Classified Instances	170	95.5056 %
Incorrectly Classified Instances	8	4.4944 %
Kappa statistic	0.9351	
Mean absolute error	0.0317	
Root mean squared error	0.1506	
Relative absolute error	9.1416 %	
Root relative squared error	36.1972 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.958	0.006	0.958	0.958	0.958	0.952	0.998	0.989	'(-inf-63.525]'
0.902	0.015	0.949	0.902	0.925	0.904	0.991	0.975	'(63.525-97.65]'
0.963	0.031	0.963	0.963	0.963	0.932	0.993	0.992	'(97.65-131.775]'
1.000	0.014	0.943	1.000	0.971	0.964	0.999	0.995	'(131.775-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 23 & 1 & 0 & 0 \\ 1 & 37 & 3 & 0 \\ 0 & 1 & 77 & 2 \\ 0 & 0 & 0 & 33 \end{bmatrix}$$
$$\begin{aligned} a &= '(-\inf - 63.525]' \\ b &= '(63.525 - 97.65]' \\ c &= '(97.65 - 131.775]' \\ d &= '(131.775 - \inf)' \end{aligned}$$

Bayes - Naive Bayes Classifier



Classifier Output

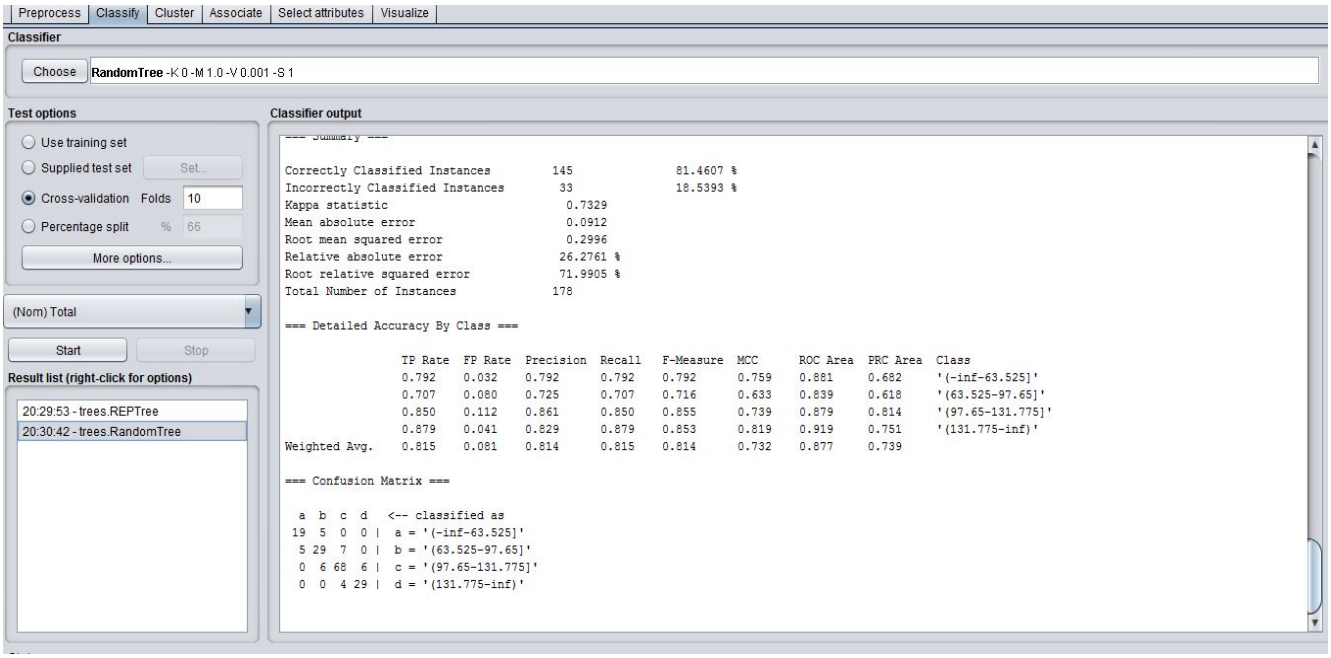
Correctly Classified Instances	167	93.8202 %
Incorrectly Classified Instances	11	6.1798 %
Kappa statistic	0.9113	
Mean absolute error	0.0322	
Root mean squared error	0.1471	
Relative absolute error	9.2759 %	
Root relative squared error	35.341 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.958	0.006	0.958	0.958	0.958	0.952	0.999	0.991	'(-inf-63.525]'
0.902	0.029	0.902	0.902	0.902	0.873	0.992	0.975	'(63.525-97.65]'
0.925	0.031	0.961	0.925	0.943	0.898	0.993	0.992	'(97.65-131.775]'
1.000	0.021	0.917	1.000	0.957	0.947	0.999	0.995	'(131.775-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 23 & 1 & 0 & 0 \\ 1 & 37 & 3 & 0 \\ 0 & 3 & 74 & 3 \\ 0 & 0 & 0 & 33 \end{bmatrix}$$
$$a = '(-\inf - 63.525]'$$
$$b = '(63.525 - 97.65]'$$
$$c = '(97.65 - 131.775]'$$
$$d = '(131.775 - \inf)'$$

Trees – Random Tree Classifier



Classifier Output

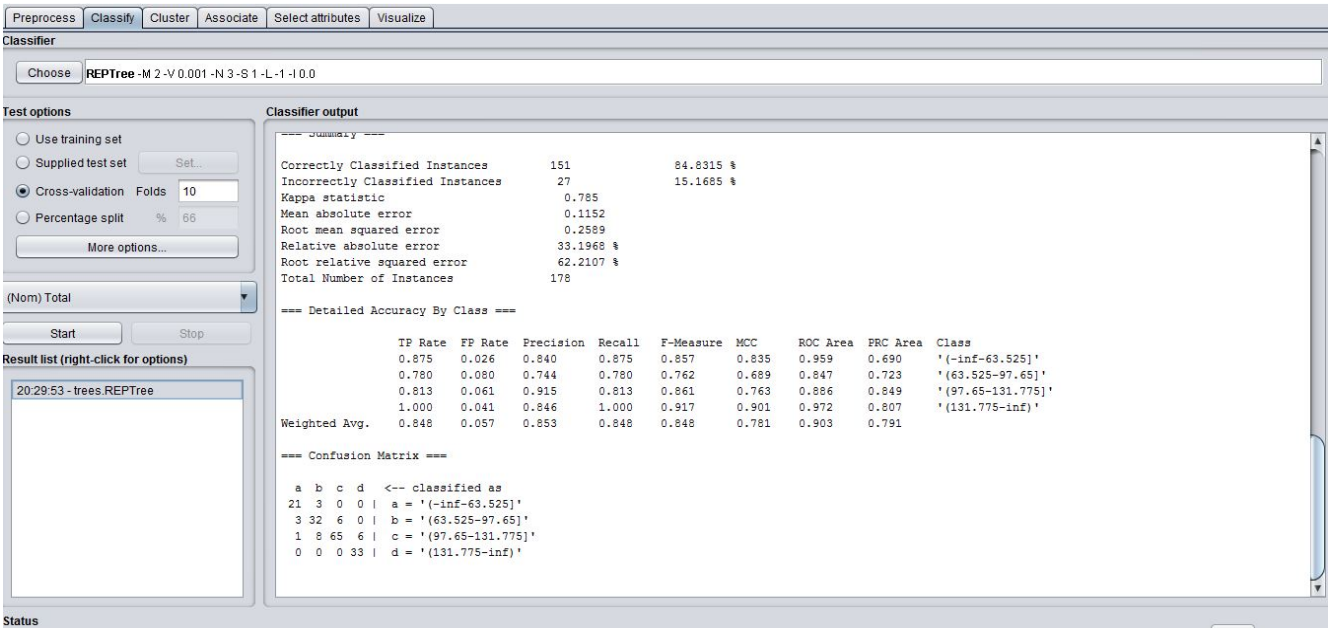
Correctly Classified Instances	145	81.4607 %
Incorrectly Classified Instances	33	18.5393 %
Kappa statistic	0.7329	
Mean absolute error	0.0912	
Root mean squared error	0.2996	
Relative absolute error	26.2761 %	
Root relative squared error	71.9905 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.792	0.032	0.792	0.792	0.792	0.759	0.881	0.682	'(-inf-63.525]'
0.707	0.080	0.725	0.707	0.716	0.633	0.839	0.618	'(63.525-97.65]'
0.850	0.112	0.861	0.850	0.855	0.739	0.879	0.814	'(97.65-131.775]'
0.879	0.041	0.829	0.879	0.853	0.819	0.919	0.751	'(131.775-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 19 & 5 & 0 & 0 \\ 5 & 29 & 7 & 0 \\ 0 & 6 & 68 & 6 \\ 0 & 0 & 4 & 29 \end{bmatrix}$$
$$a = '(-\inf - 63.525]'$$
$$b = '(63.525 - 97.65]'$$
$$c = '(97.65 - 131.775]'$$
$$d = '(131.775 - \inf)'$$

Trees – REP Tree Classifier



Classifier Output

Correctly Classified Instances	151	84.8315 %
Incorrectly Classified Instances	27	15.1685 %
Kappa statistic	0.785	
Mean absolute error	0.1152	
Root mean squared error	0.2589	
Relative absolute error	33.1968 %	
Root relative squared error	62.2107 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.875	0.026	0.840	0.875	0.857	0.835	0.959	0.690	'(-inf-63.525]'
0.780	0.080	0.744	0.780	0.762	0.689	0.847	0.723	'(63.525-97.65]'
0.813	0.061	0.915	0.813	0.861	0.763	0.886	0.849	'(97.65-131.775]'
1.000	0.041	0.846	1.000	0.917	0.901	0.972	0.807	'(131.775-inf)'

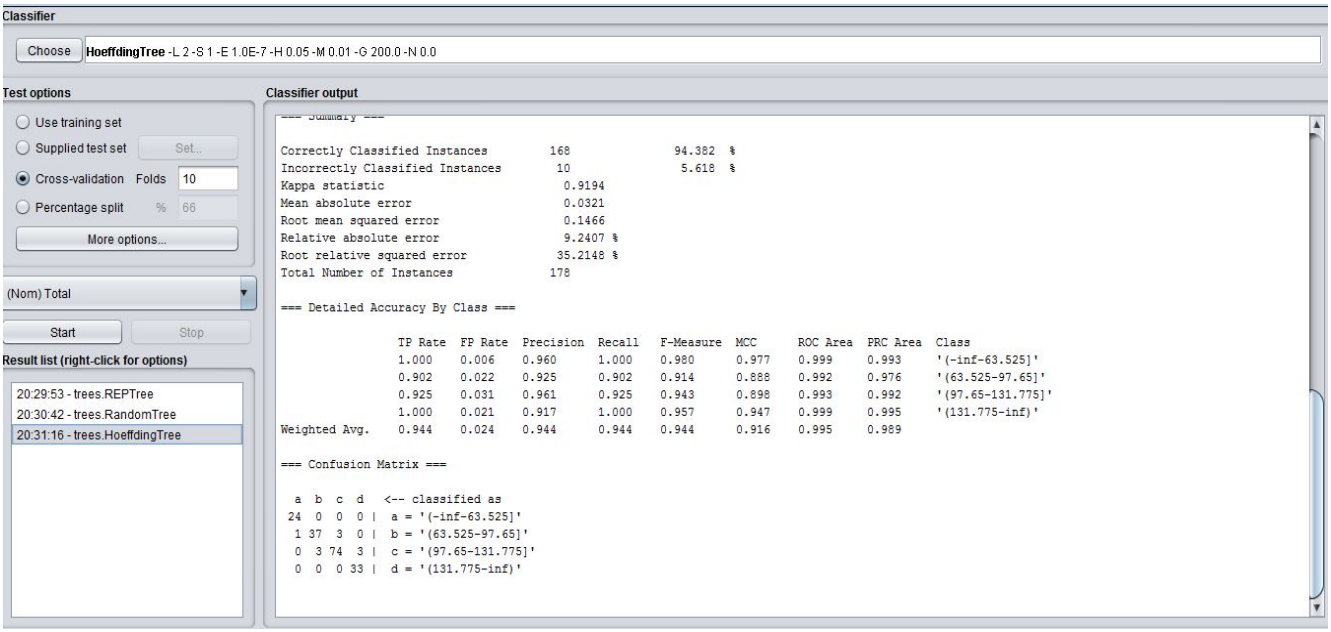
Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$

$$\begin{bmatrix} 21 & 3 & 0 & 0 \\ 3 & 32 & 6 & 0 \\ 1 & 8 & 65 & 6 \\ 0 & 0 & 0 & 33 \end{bmatrix}$$

$$\begin{aligned} a &= '(-\inf - 63.525]' \\ b &= '(63.525 - 97.65]' \\ c &= '(97.65 - 131.775]' \\ d &= '(131.775 - \inf)' \end{aligned}$$

Trees – Hoeffding Tree Classifier



Classifier Output

Correctly Classified Instances	168	94.382 %
Incorrectly Classified Instances	10	5.618 %
Kappa statistic	0.9194	
Mean absolute error	0.0321	
Root mean squared error	0.1466	
Relative absolute error	9.2407 %	
Root relative squared error	35.2148 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
1.000	0.006	0.960	1.000	0.980	0.977	0.999	0.993	'(-inf-63.525]'
0.902	0.022	0.925	0.902	0.914	0.888	0.992	0.976	'(63.525-97.65]'
0.925	0.031	0.961	0.925	0.943	0.898	0.993	0.992	'(97.65-131.775]'
1.000	0.021	0.917	1.000	0.957	0.947	0.999	0.995	'(131.775-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 24 & 0 & 0 & 0 \\ 1 & 37 & 3 & 0 \\ 0 & 3 & 74 & 3 \\ 0 & 0 & 0 & 33 \end{bmatrix}$$

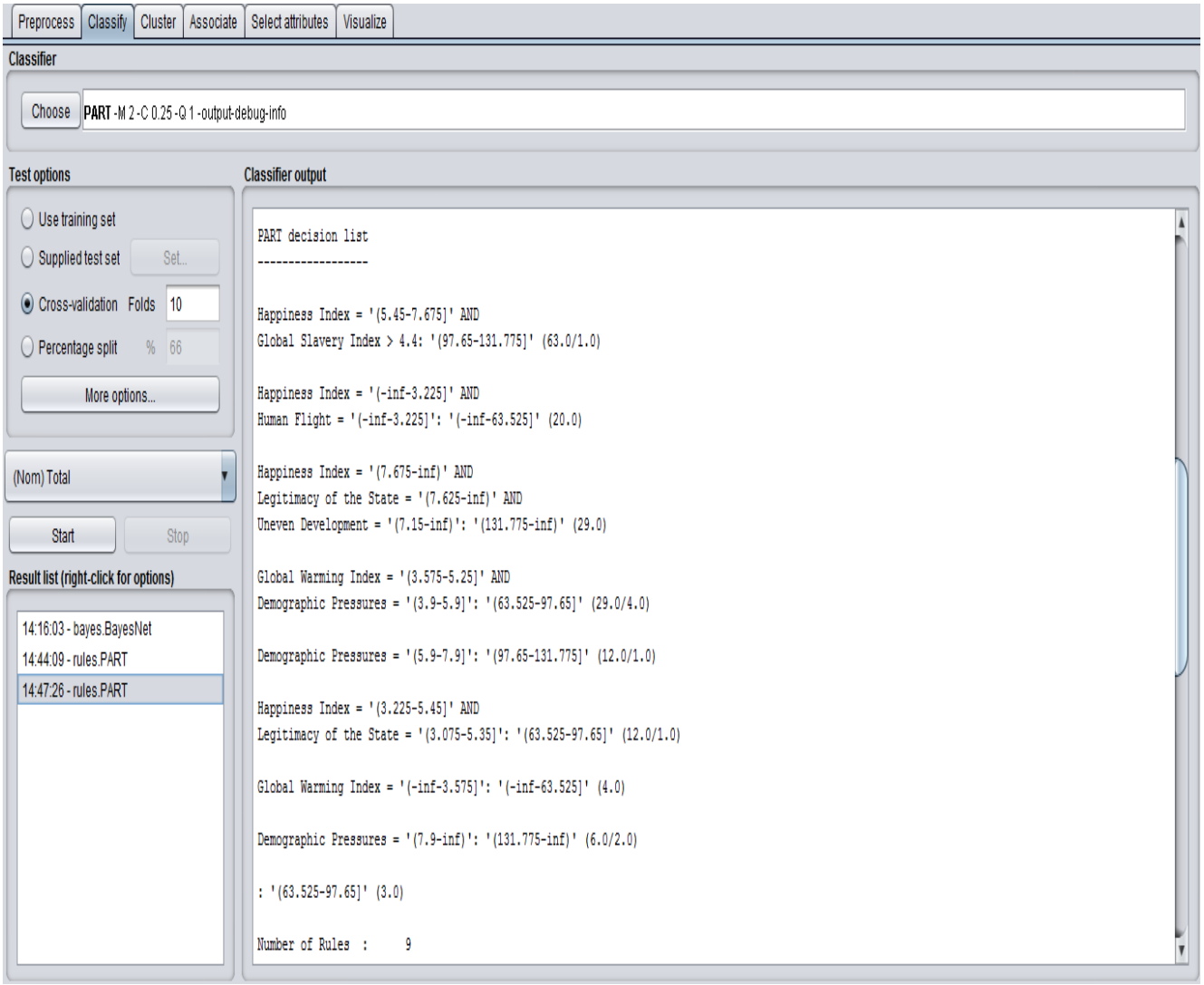
$$a = '(-\inf - 63.525]'$$
$$b = '(63.525 - 97.65]'$$
$$c = '(97.65 - 131.775]'$$
$$d = '(131.775 - \inf)'$$

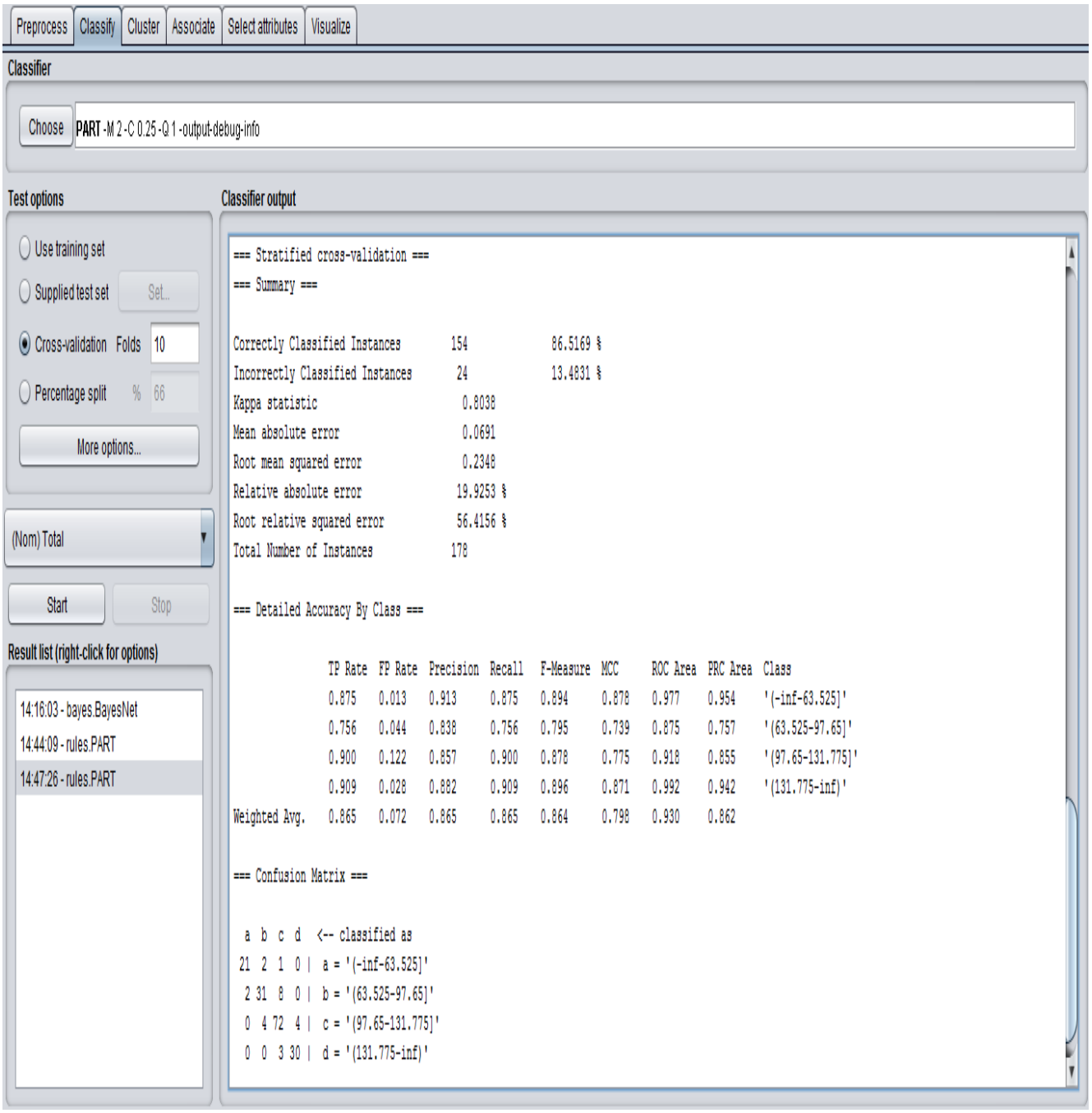
Comparison of Algorithms and Result

Since the percentage of correctly classified instances for Bayes Net, Naïve Bayes, Random Tree, REP Tree and Hoeffding Tree algorithms is 95.5056, 93.8202, 81.4607, 84.8315 and 94.382 respectively. This clearly shows that Bayes Net algorithm is best used to classify as it has high accuracy when compared with other algorithms.

Determining Action Rules

We have determined the action rules by using Weka by selecting the Rules-PART filter as the classifier and run for the data with total as the decision attribute. The rules are logged in a word document and the result screenshot is shown below.





Year 2013

Discretize

We have Total as the decision feature. In the data set, the total column is sorted. Since we have to split the total into 4 intervals, we can split it as the levels Alert, Warning, Stable and Sustainable. We need to choose the split to get a maximum entropy gain for the decision feature considered.

Alert 35 Warning 78 Stable 42 Sustainable 23

Entropy Gain for Total

E(D) = -(((35/178) * $\log_4$(35/178)) + ((78/178) * $\log_4$(78/178)) + ((42/178) * $\log_4$(42/178)) + ((23/178) * $\log_4$(23/178)))
E(D) = -(0.196629213*(-1.173225207) + 0.438202247*(-0.595165606) + 0.235955056*(-1.041708004) + 0.129213483*(-1.476085737))
E(D) = 0.928019706

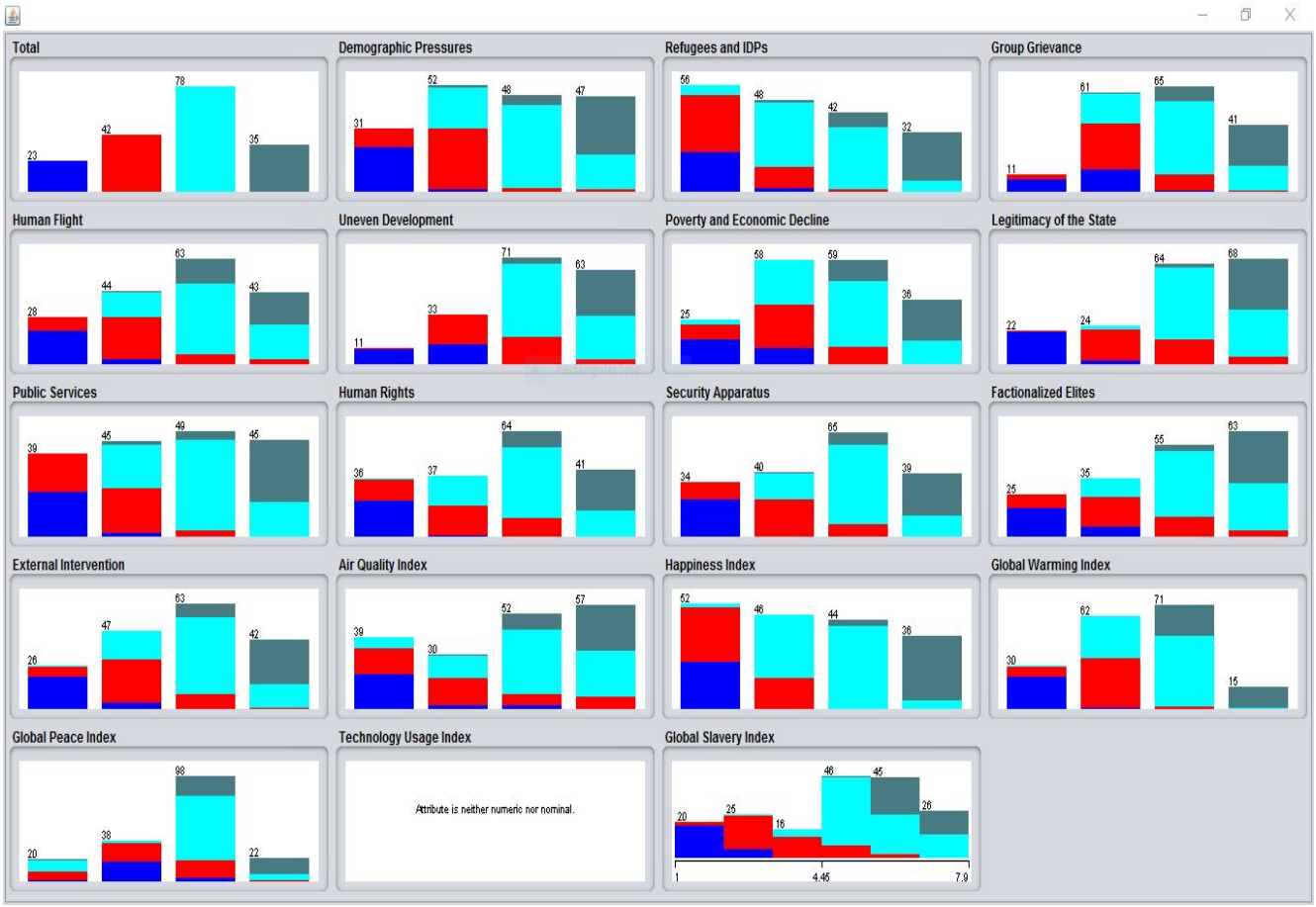
We have calculated the initial entropy and made the split based on the entropy gain of the split. We have chosen the split which has higher Entropy Gain and decided to have the total split into 4 intervals as below

(129.825 … +infinity) (95.65 … 129.825] (61.475 … 95.65] (-infinity … 61.475]

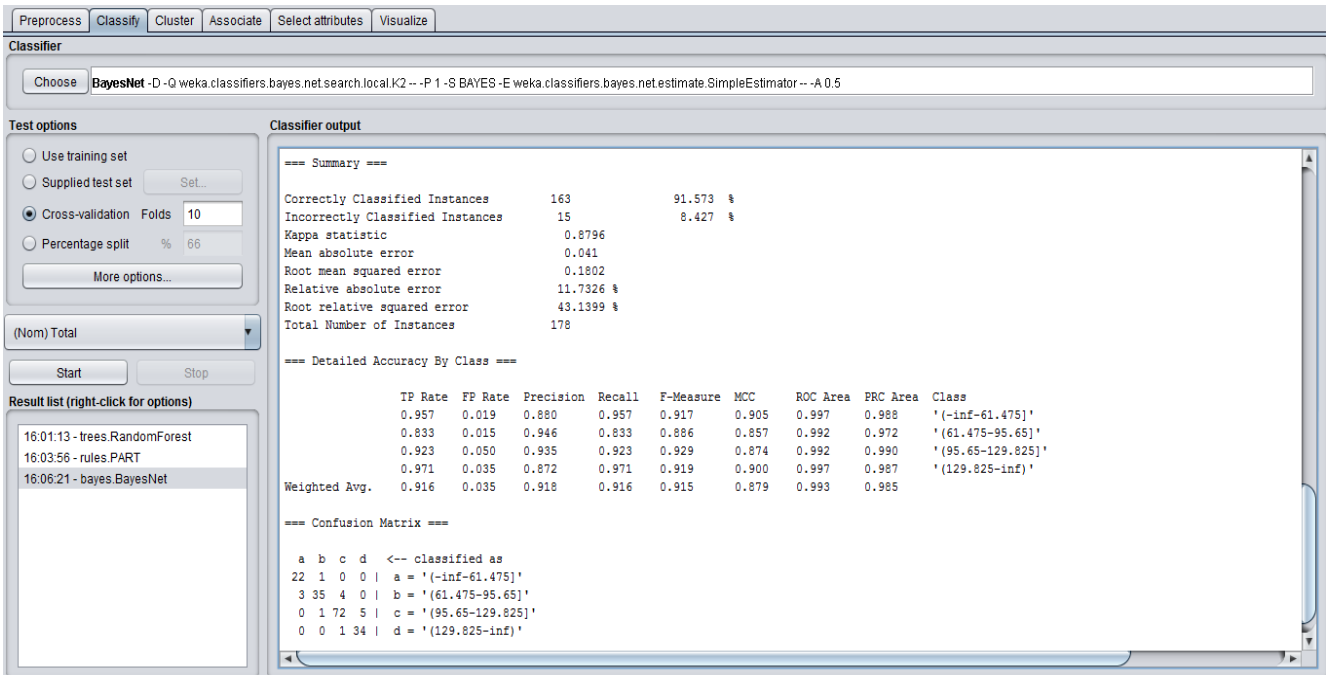
Classification using WEKA

Select Total as the decision feature and apply different algorithms to compare the results and choose the algorithm that gives the best number of correctly classified records.

Visualize all the features



Bayes – BayesNet Classifier



Classifier Output

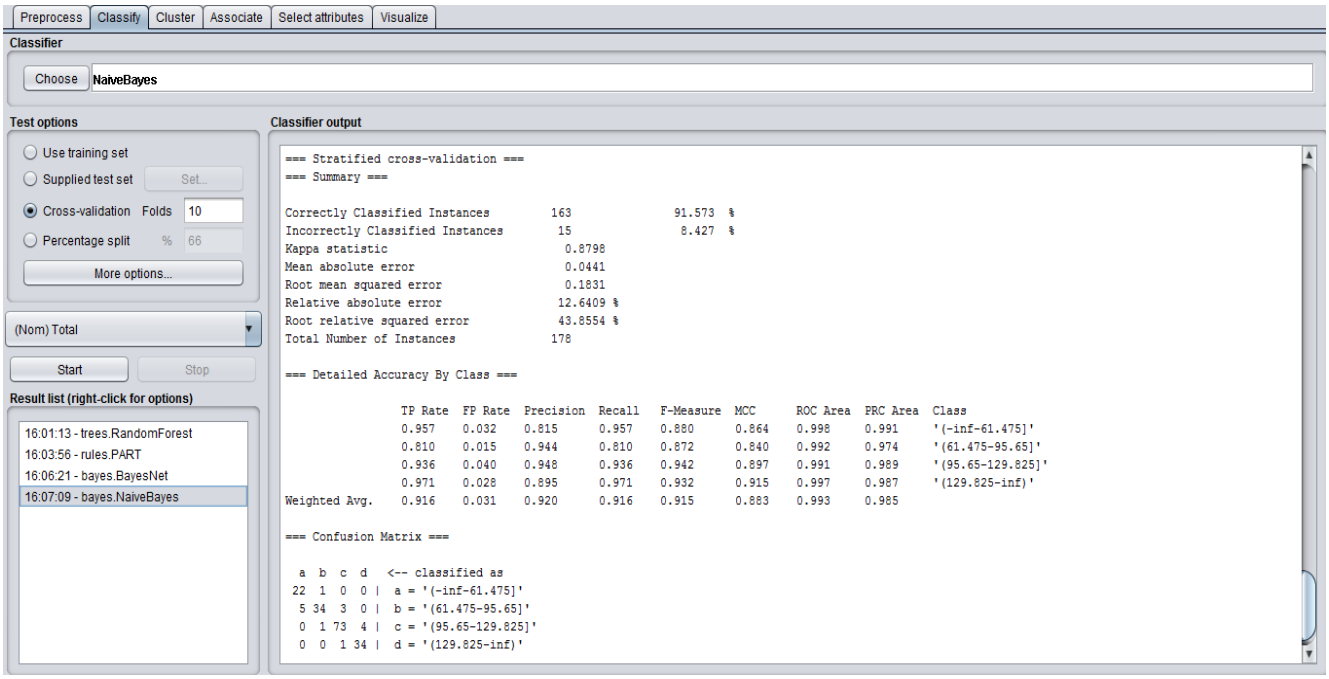
Correctly Classified Instances	163	91.573 %
Incorrectly Classified Instances	15	8.427 %
Kappa statistic	0.8796	
Mean absolute error	0.041	
Root mean squared error	0.1802	
Relative absolute error	11.7326 %	
Root relative squared error	43.1399 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.957	0.019	0.880	0.957	0.917	0.905	0.997	0.988	'(-inf-61.475]'
0.833	0.015	0.946	0.833	0.886	0.857	0.992	0.972	'(61.475-95.65]'
0.923	0.050	0.935	0.923	0.929	0.874	0.992	0.990	'(95.65-129.825]'
0.971	0.035	0.872	0.971	0.919	0.900	0.997	0.987	'(129.825-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 22 & 1 & 0 & 0 \\ 3 & 35 & 4 & 0 \\ 0 & 1 & 72 & 5 \\ 0 & 0 & 1 & 34 \end{bmatrix}$$
$$\begin{aligned} a &= '(-\inf - 61.475]' \\ b &= '(61.475 - 95.65]' \\ c &= '(95.65 - 129.825]' \\ d &= '(129.825 - \inf)' \end{aligned}$$

Bayes – Naive Bayes Classifier



Classifier Output

Correctly Classified Instances	163	91.573 %
Incorrectly Classified Instances	15	8.427 %
Kappa statistic	0.8798	
Mean absolute error	0.0441	
Root mean squared error	0.1831	
Relative absolute error	12.6409 %	
Root relative squared error	43.8554 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.957	0.032	0.815	0.957	0.880	0.864	0.998	0.991	'(-inf-61.475]'
0.810	0.015	0.944	0.810	0.872	0.840	0.992	0.974	'(61.475-95.65]'
0.936	0.040	0.948	0.936	0.942	0.897	0.991	0.989	'(95.65-129.825]'
0.971	0.028	0.895	0.971	0.932	0.915	0.997	0.987	'(129.825-inf)'

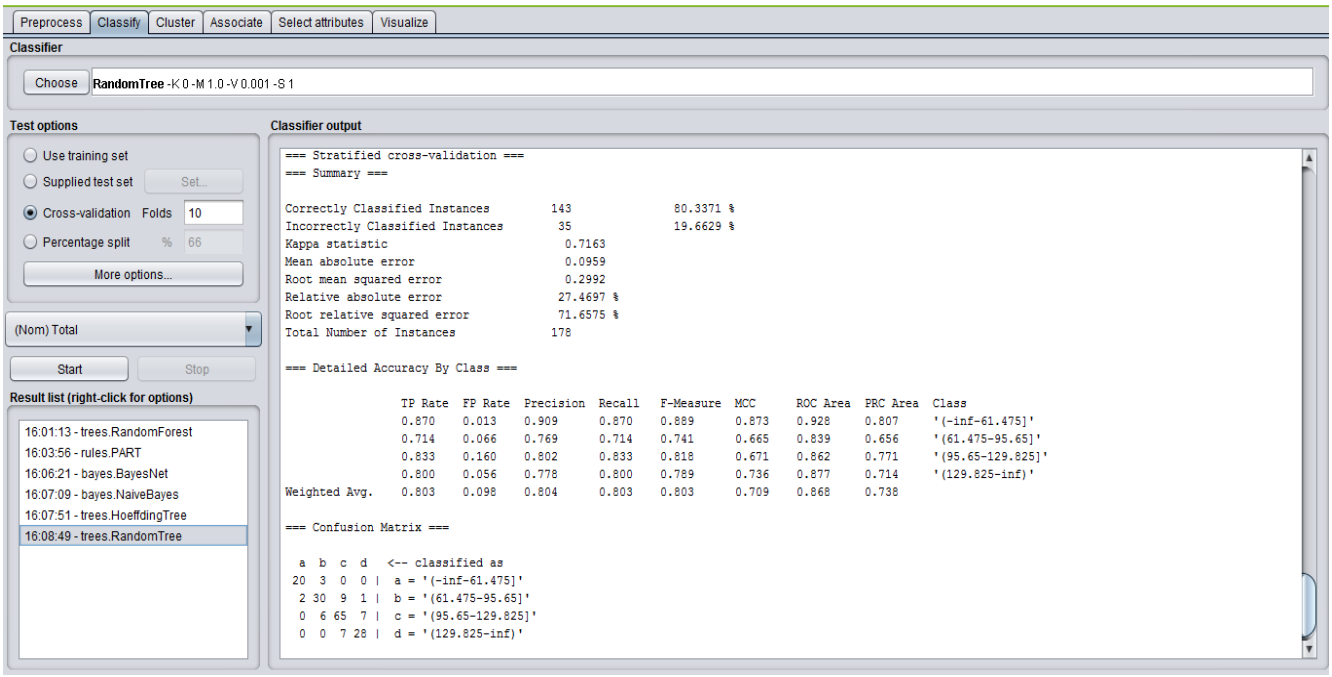
Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$

$$\begin{bmatrix} 22 & 1 & 0 & 0 \\ 5 & 34 & 3 & 0 \\ 0 & 1 & 73 & 4 \\ 0 & 0 & 1 & 34 \end{bmatrix}$$

$$\begin{aligned} a &= '(-\inf - 61.475]' \\ b &= '(61.475 - 95.65]' \\ c &= '(95.65 - 129.825]' \\ d &= '(129.825 - \inf)' \end{aligned}$$

Trees – Random Tree Classifier



Classifier Output

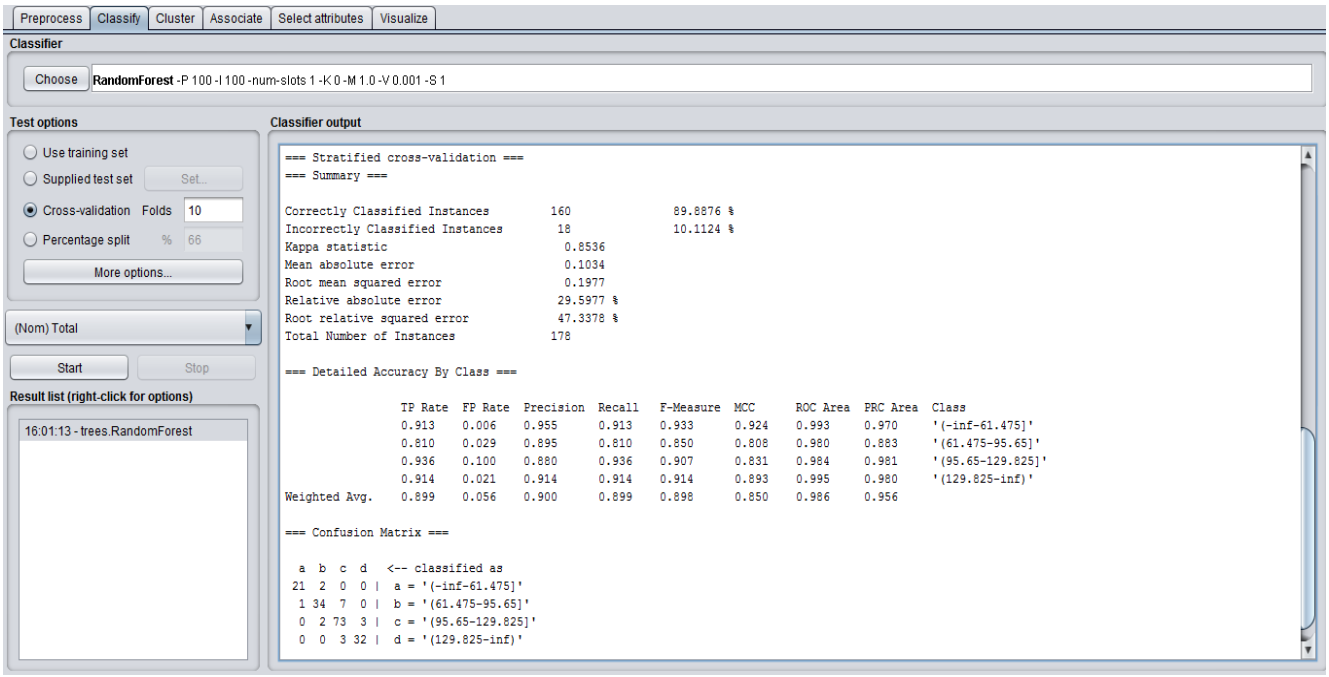
Correctly Classified Instances	143	80.3371 %
Incorrectly Classified Instances	35	19.6629 %
Kappa statistic	0.7163	
Mean absolute error	0.0959	
Root mean squared error	0.2992	
Relative absolute error	27.4697 %	
Root relative squared error	71.6575 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.870	0.013	0.909	0.870	0.889	0.873	0.928	0.807	'(-inf-61.475]'
0.714	0.066	0.769	0.714	0.741	0.665	0.839	0.656	'(61.475-95.65]'
0.833	0.160	0.802	0.833	0.818	0.671	0.862	0.771	'(95.65-129.825]'
0.800	0.056	0.778	0.800	0.789	0.736	0.877	0.714	'(129.825-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 20 & 3 & 0 & 0 \\ 2 & 30 & 9 & 1 \\ 0 & 6 & 65 & 7 \\ 0 & 0 & 7 & 28 \end{bmatrix}$$
$$\begin{aligned} a &= '(-\inf - 61.475]' \\ b &= '(61.475 - 95.65]' \\ c &= '(95.65 - 129.825]' \\ d &= '(129.825 - \inf)' \end{aligned}$$

Trees – Random Forest Classifier



Classifier Output

Correctly Classified Instances	160	89.8876 %
Incorrectly Classified Instances	18	10.1124 %
Kappa statistic	0.8536	
Mean absolute error	0.1034	
Root mean squared error	0.1977	
Relative absolute error	29.5977 %	
Root relative squared error	47.3378 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.913	0.006	0.955	0.913	0.933	0.924	0.993	0.970	'(-inf-61.475]'
0.810	0.029	0.895	0.810	0.850	0.808	0.980	0.883	'(61.475-95.65]'
0.936	0.100	0.880	0.936	0.907	0.831	0.984	0.981	'(95.65-129.825]'
0.914	0.021	0.914	0.914	0.914	0.893	0.995	0.980	'(129.825-inf)'

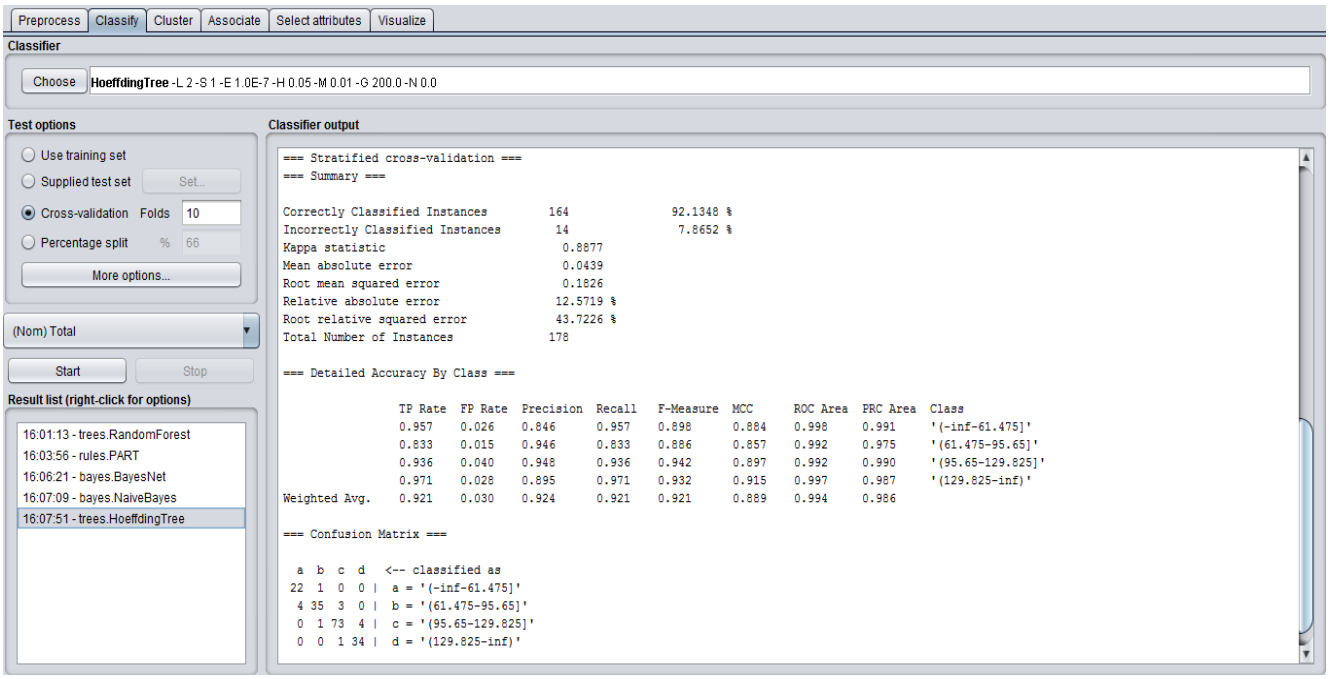
Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$

$$\begin{bmatrix} 21 & 2 & 0 & 0 \\ 1 & 34 & 7 & 0 \\ 0 & 2 & 73 & 3 \\ 0 & 0 & 3 & 32 \end{bmatrix}$$

$$\begin{aligned} a &= '(-\inf - 61.475]' \\ b &= '(61.475 - 95.65]' \\ c &= '(95.65 - 129.825]' \\ d &= '(129.825 - \inf)' \end{aligned}$$

Trees – Hoeffding Tree Classifier



Classifier Output

Correctly Classified Instances	164	92.1348 %
Incorrectly Classified Instances	14	7.8652 %
Kappa statistic	0.8877	
Mean absolute error	0.0439	
Root mean squared error	0.1826	
Relative absolute error	12.5719 %	
Root relative squared error	43.7226 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.957	0.026	0.846	0.957	0.898	0.884	0.998	0.991	'(-inf-61.475]'
0.833	0.015	0.946	0.833	0.886	0.857	0.992	0.975	'(61.475-95.65]'
0.936	0.040	0.948	0.936	0.942	0.897	0.992	0.990	'(95.65-129.825]'
0.971	0.028	0.895	0.971	0.932	0.915	0.997	0.987	'(129.825-inf)'

Confusion Matrix

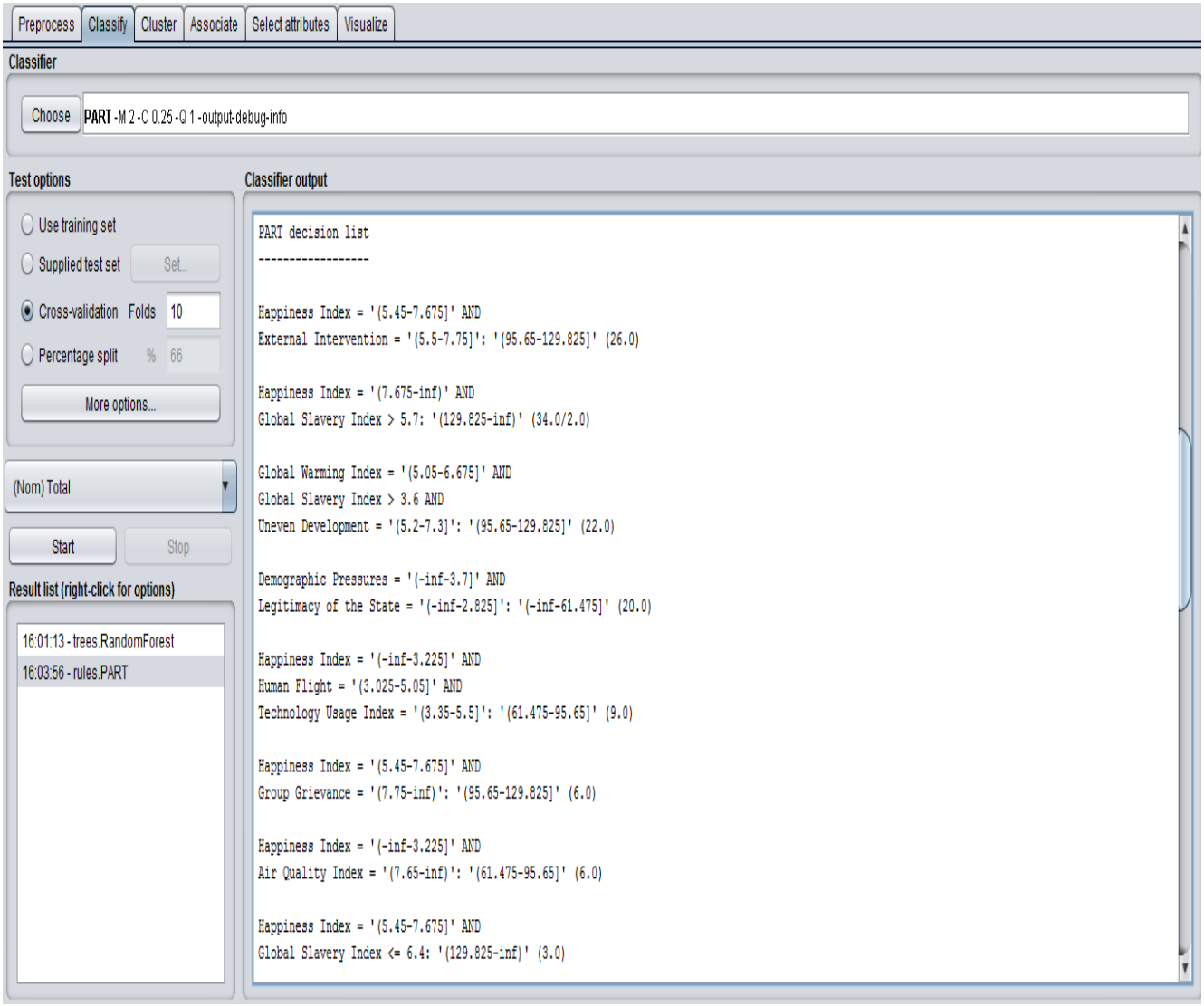
$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 22 & 1 & 0 & 0 \\ 4 & 35 & 3 & 0 \\ 0 & 1 & 73 & 4 \\ 0 & 0 & 1 & 34 \end{bmatrix}$$
$$a = '(-\inf - 61.475]'$$
$$b = '(61.475 - 95.65]'$$
$$c = '(95.65 - 129.825]'$$
$$d = '(129.825 - \inf)'$$

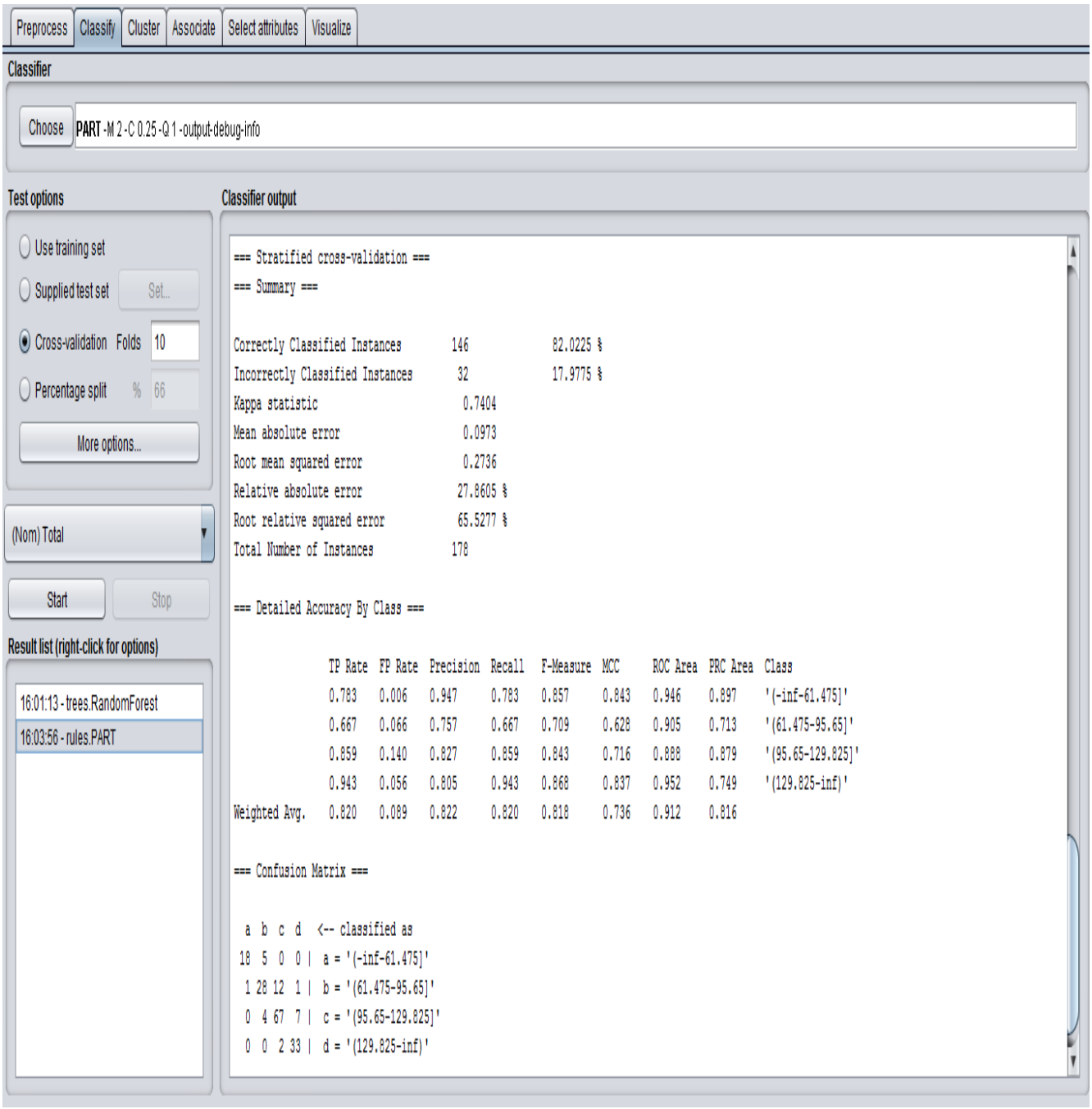
Comparison of Algorithms and Result

Since the percentage of correctly classified instances for Bayes Net, Naïve Bayes, Random Tree, Random Forest and Hoeffding Tree algorithms is 91.573, 91.573, 80.3371, 89.8876, 92.1348 respectively. This clearly shows that Hoeffding Tree algorithm is best used to classify as it has high accuracy when compared with other algorithms.

Determining Action Rules

We have determined the action rules by using Weka by selecting the Rules-PART filter as the classifier and run for the data with total as the decision attribute. The rules are logged in a word document and the result screenshot is shown below.





Year 2014

Discretize

We have Total as the decision feature. In the data set, the total column is sorted. Since we have to split the total into 4 intervals, we can split it as the levels Alert, Warning, Stable and Sustainable. We need to choose the split to get a maximum entropy gain for the decision feature considered.

Alert 36 Warning 79 Stable 38 Sustainable 25

Entropy Gain for Total

E(D) = -(((36/178) * $\log_4$(36/178)) + ((79/178) * $\log_4$(79/178)) + ((38/178) * $\log_4$(38/178)) + ((25/178) * $\log_4$(25/178)))
E(D) = -(0.202247191*(-1.152904215) + 0.443820225*(-0.585976341) + 0.213483146*(-1.113902959) + 0.140449438*(-1.415938621))
E(D) = 0.929907082

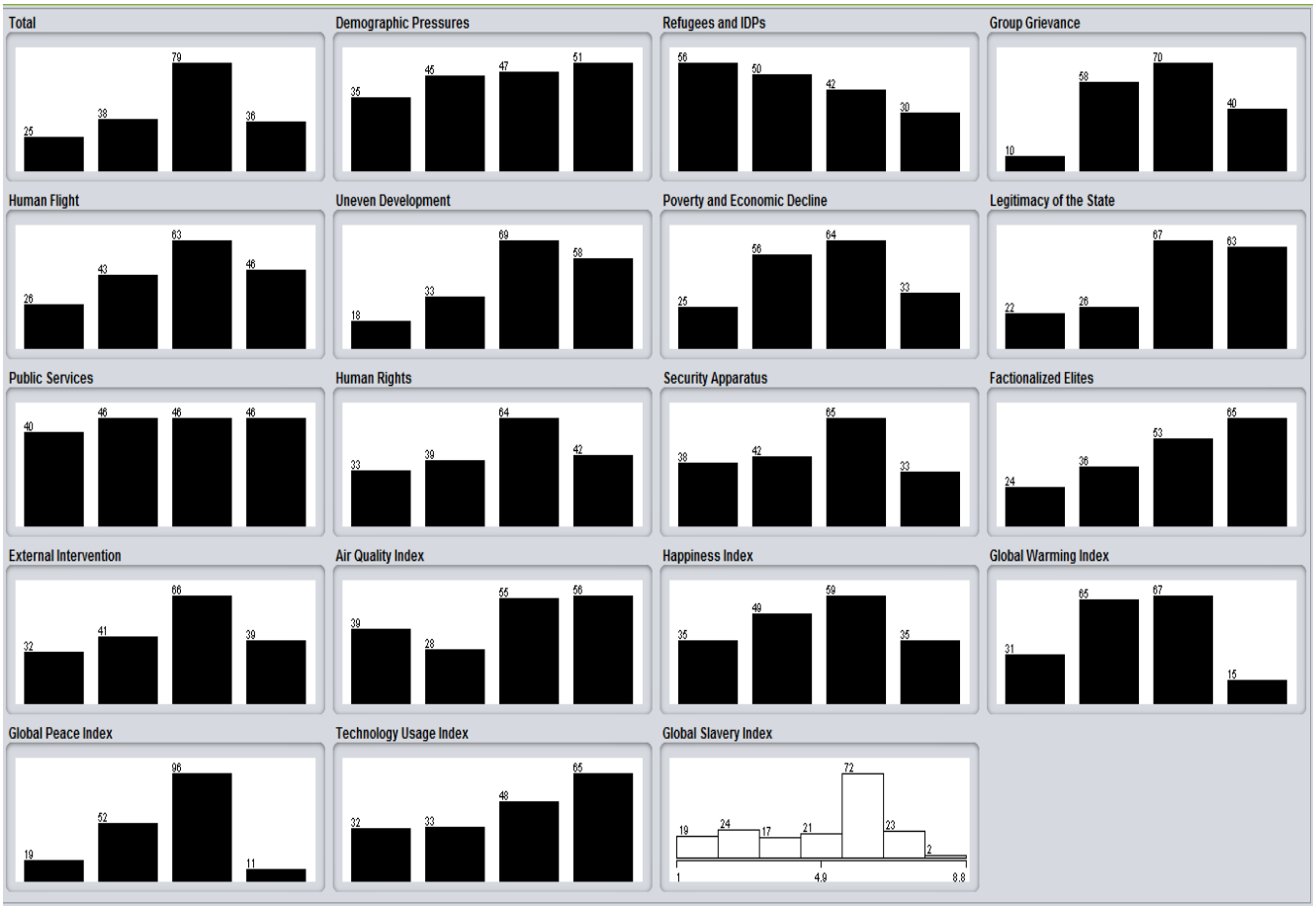
We have calculated the initial entropy and made the split based on the entropy gain of the split. We have chosen the split which has higher Entropy Gain and decided to have the total split into 4 intervals as below

(129.3 … +infinity) (95.6 … 129.3] (61.9 … 95.6] (-infinity … 61.9]

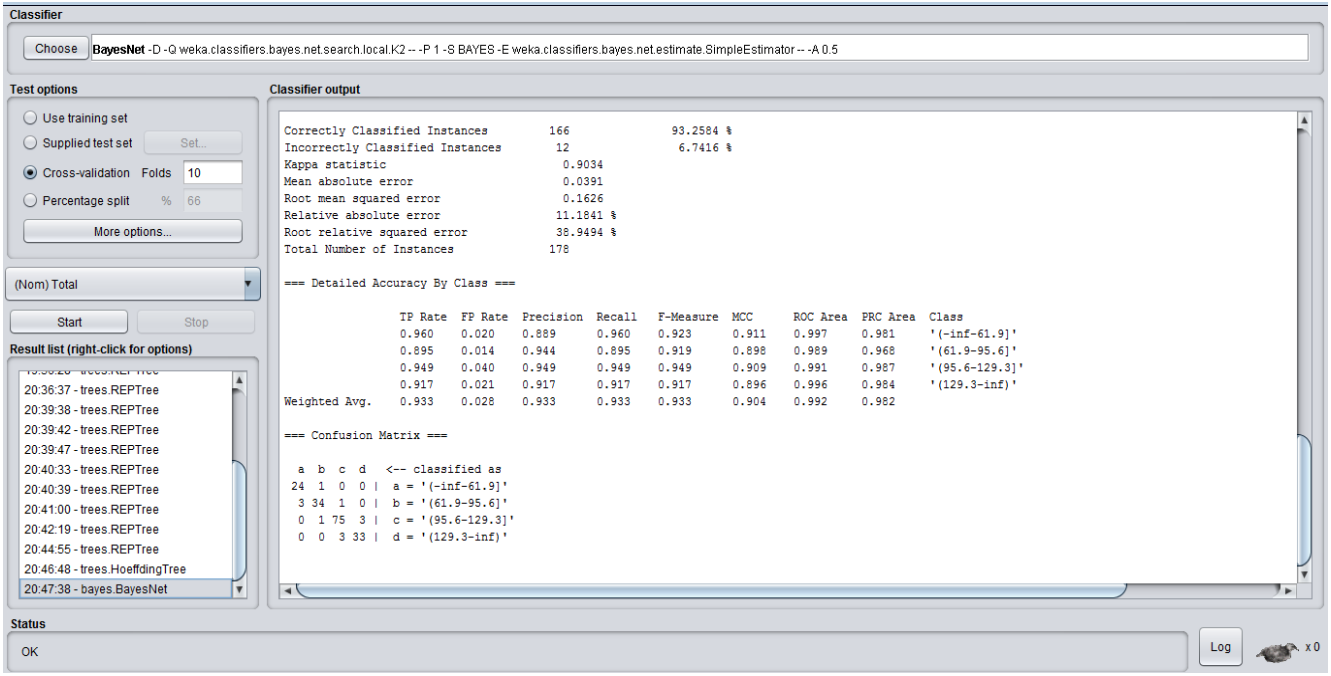
Classification using WEKA

Select Total as the decision feature and apply different algorithms to compare the results and choose the algorithm that gives the best number of correctly classified records.

Visualize all the features



Bayes - BayesNet Classifier



Classifier Output

Correctly Classified Instances	166	93.2548 %
Incorrectly Classified Instances	12	6.7416 %
Kappa statistic	0.9034	
Mean absolute error	0.0391	
Root mean squared error	0.1626	
Relative absolute error	11.1841 %	
Root relative squared error	38.9494 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.960	0.020	0.889	0.960	0.923	0.911	0.997	0.981	'(-inf-61.9]'
0.895	0.014	0.944	0.895	0.919	0.898	0.989	0.968	'(61.9-95.6]'
0.949	0.040	0.949	0.949	0.949	0.909	0.991	0.987	'(95.6-129.3]'
0.917	0.021	0.917	0.917	0.917	0.896	0.996	0.984	'(129.3-inf)'

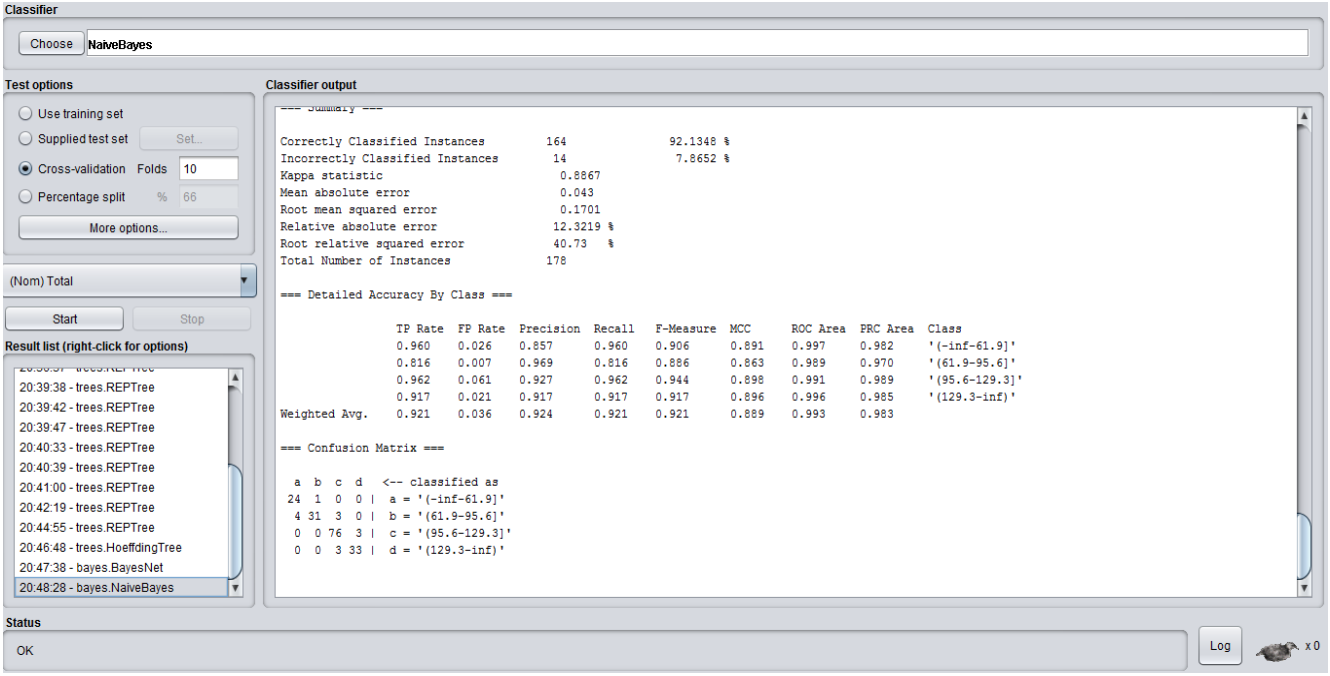
Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$

$$\begin{bmatrix} 24 & 1 & 0 & 0 \\ 3 & 34 & 1 & 0 \\ 0 & 1 & 75 & 3 \\ 0 & 0 & 3 & 33 \end{bmatrix}$$

$$\begin{aligned} a &= '(-\inf - 61.9]' \\ b &= '(61.9 - 95.6]' \\ c &= '(95.6 - 129.3]' \\ d &= '(129.3 - \inf)' \end{aligned}$$

Bayes - Naive Bayes Classifier



Classifier Output

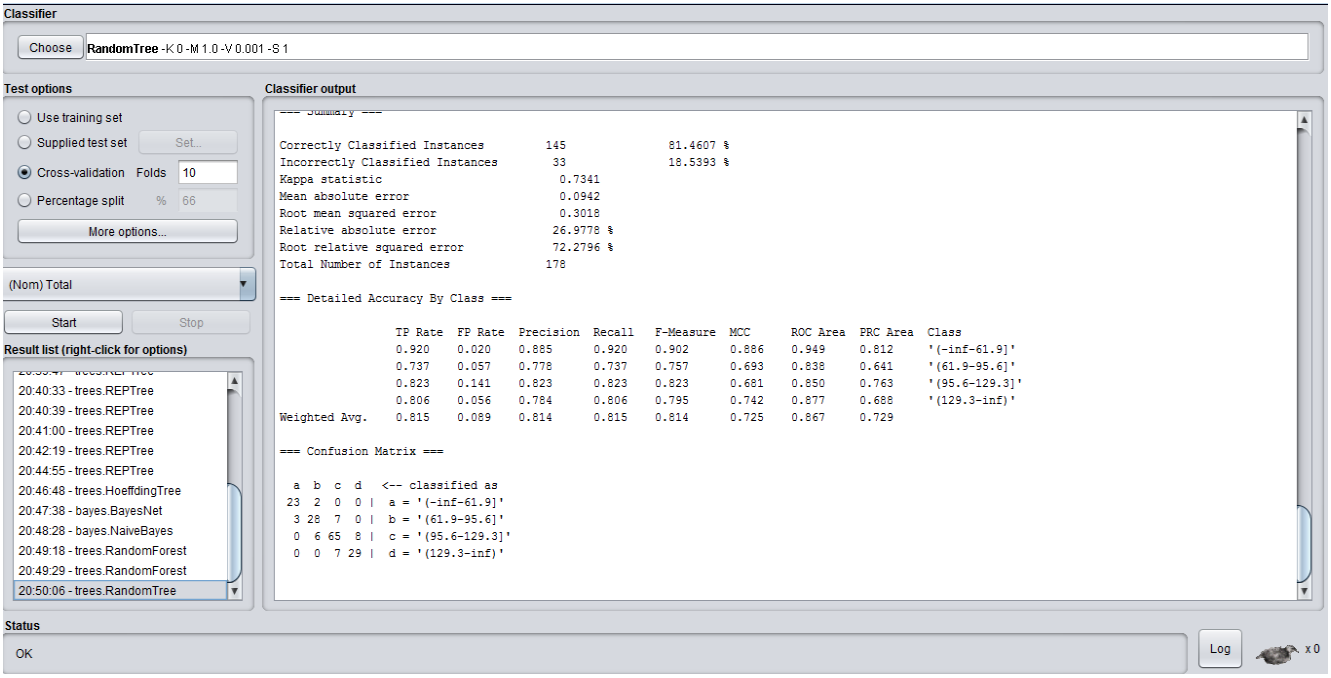
Correctly Classified Instances	164	92.1348 %
Incorrectly Classified Instances	14	7.8652 %
Kappa statistic	0.8867	
Mean absolute error	0.043	
Root mean squared error	0.1701	
Relative absolute error	12.3219 %	
Root relative squared error	40.73 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.960	0.026	0.857	0.958	0.960	0.891	0.997	0.982	'(-inf-61.9]'
0.816	0.007	0.969	0.902	0.886	0.863	0.989	0.970	'(61.9-95.6]'
0.962	0.061	0.927	0.963	0.944	0.898	0.993	0.989	'(95.6-129.3]'
0.917	0.021	0.917	1.000	0.917	0.896	0.999	0.985	'(129.3-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 24 & 1 & 0 & 0 \\ 4 & 31 & 3 & 0 \\ 0 & 0 & 76 & 3 \\ 0 & 0 & 3 & 33 \end{bmatrix}$$
$$a = '(-\inf - 61.9]'$$
$$b = '(61.9 - 95.6]'$$
$$c = '(95.6 - 129.3]'$$
$$d = '(129.3 - \inf)'$$

Trees – Random Tree Classifier



Classifier Output

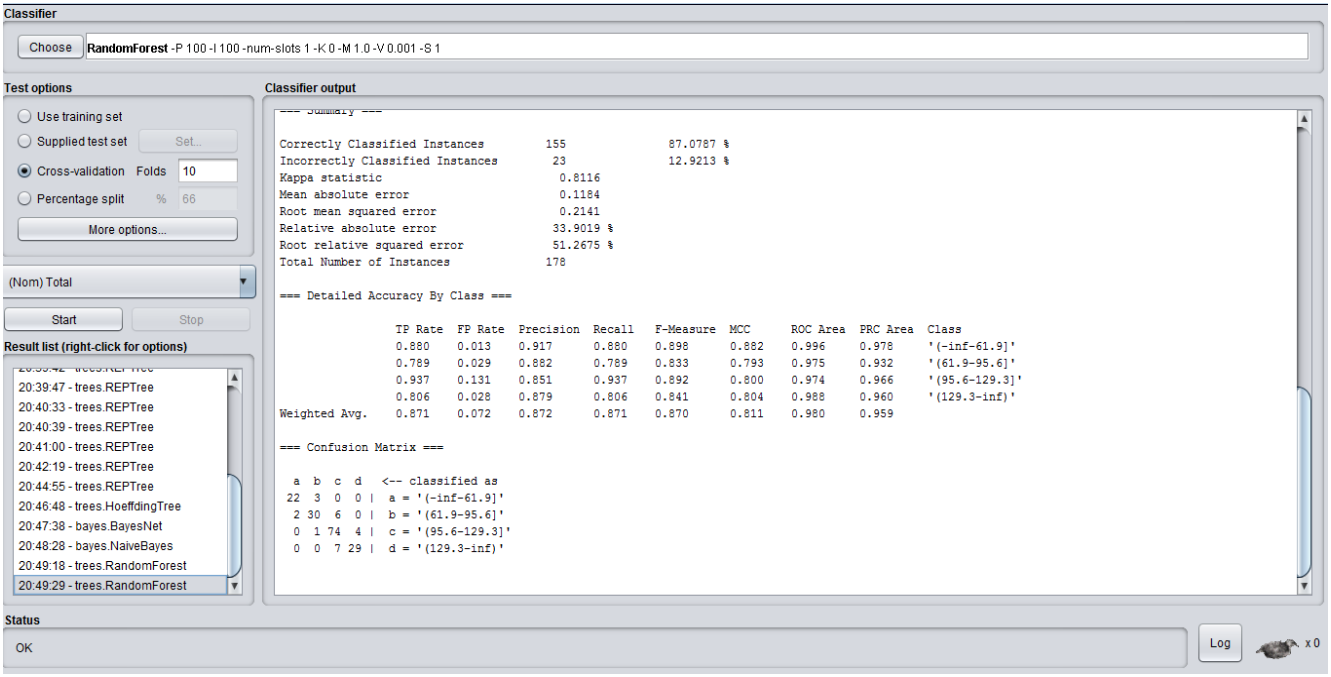
Correctly Classified Instances	145	81.4607 %
Incorrectly Classified Instances	33	18.5393 %
Kappa statistic	0.7341	
Mean absolute error	0.0942	
Root mean squared error	0.3018	
Relative absolute error	26.9778 %	
Root relative squared error	72.2796 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.920	0.020	0.885	0.920	0.902	0.886	0.949	0.812	'(-inf-61.9]'
0.737	0.057	0.778	0.737	0.757	0.693	0.838	0.641	'(61.9-95.6]'
0.823	0.141	0.823	0.823	0.823	0.681	0.850	0.763	'(95.6-129.3]'
0.806	0.056	0.784	0.795	0.795	0.742	0.877	0.688	'(129.3-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 23 & 2 & 0 & 0 \\ 3 & 28 & 7 & 0 \\ 0 & 6 & 65 & 8 \\ 0 & 0 & 7 & 29 \end{bmatrix}$$
$$a = '(-\inf - 61.9]'$$
$$b = '(61.9 - 95.6]'$$
$$c = '(95.6 - 129.3]'$$
$$d = '(129.3 - \inf)'$$

Trees – Random Forest Classifier



Classifier Output

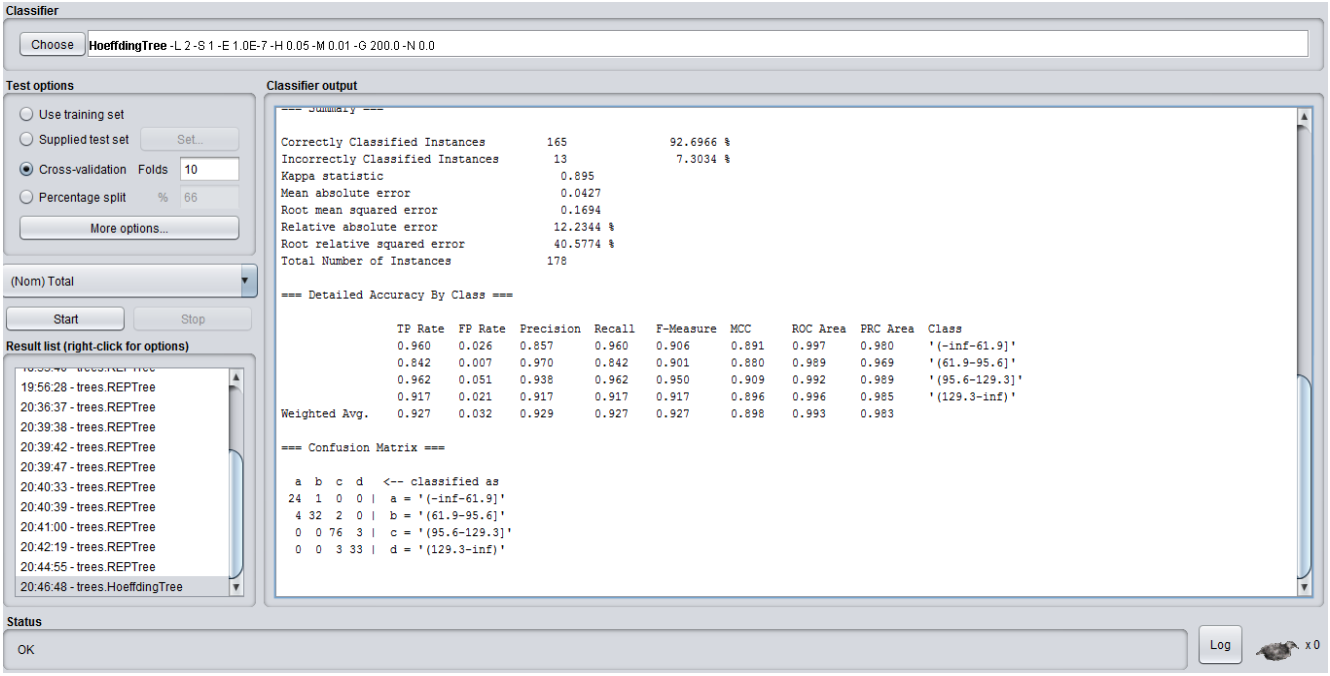
Correctly Classified Instances	155	87.0787 %
Incorrectly Classified Instances	23	12.9213 %
Kappa statistic	0.8116	
Mean absolute error	0.1184	
Root mean squared error	0.2141	
Relative absolute error	33.9019 %	
Root relative squared error	51.2675 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.880	0.013	0.917	0.880	0.898	0.882	0.996	0.978	'(-inf-61.9]'
0.789	0.029	0.882	0.789	0.833	0.793	0.975	0.932	'(61.9-95.6]'
0.937	0.0131	0.851	0.937	0.892	0.800	0.974	0.966	'(95.6-129.3]'
0.806	0.028	0.879	0.806	0.841	0.804	0.988	0.960	'(129.3-inf)'

Confusion Matrix

$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 22 & 3 & 0 & 0 \\ 2 & 30 & 6 & 0 \\ 0 & 1 & 74 & 4 \\ 0 & 0 & 7 & 29 \end{bmatrix}$$
$$a = '(-\text{inf} - 61.9]'$$
$$b = '(61.9 - 95.6]'$$
$$c = '(95.6 - 129.3]'$$
$$d = '(129.3 - \text{inf})'$$

Trees – Hoeffding Tree Classifier



Classifier Output

Correctly Classified Instances	165	95.5056 %
Incorrectly Classified Instances	13	4.4944 %
Kappa statistic	0.895	
Mean absolute error	0.0427	
Root mean squared error	0.1694	
Relative absolute error	12.2344 %	
Root relative squared error	40.5774 %	
Total Number of Instances	178	

TP	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.960	0.026	0.857	0.960	0.906	0.891	0.997	0.980	'(-inf-61.9]'
0.842	0.007	0.970	0.842	0.901	0.880	0.989	0.969	'(61.9-95.6]'
0.962	0.051	0.938	0.962	0.950	0.909	0.992	0.989	'(95.6-129.3]'
0.917	0.021	0.917	0.927	0.917	0.896	0.996	0.985	'(129.3-inf)'

Confusion Matrix

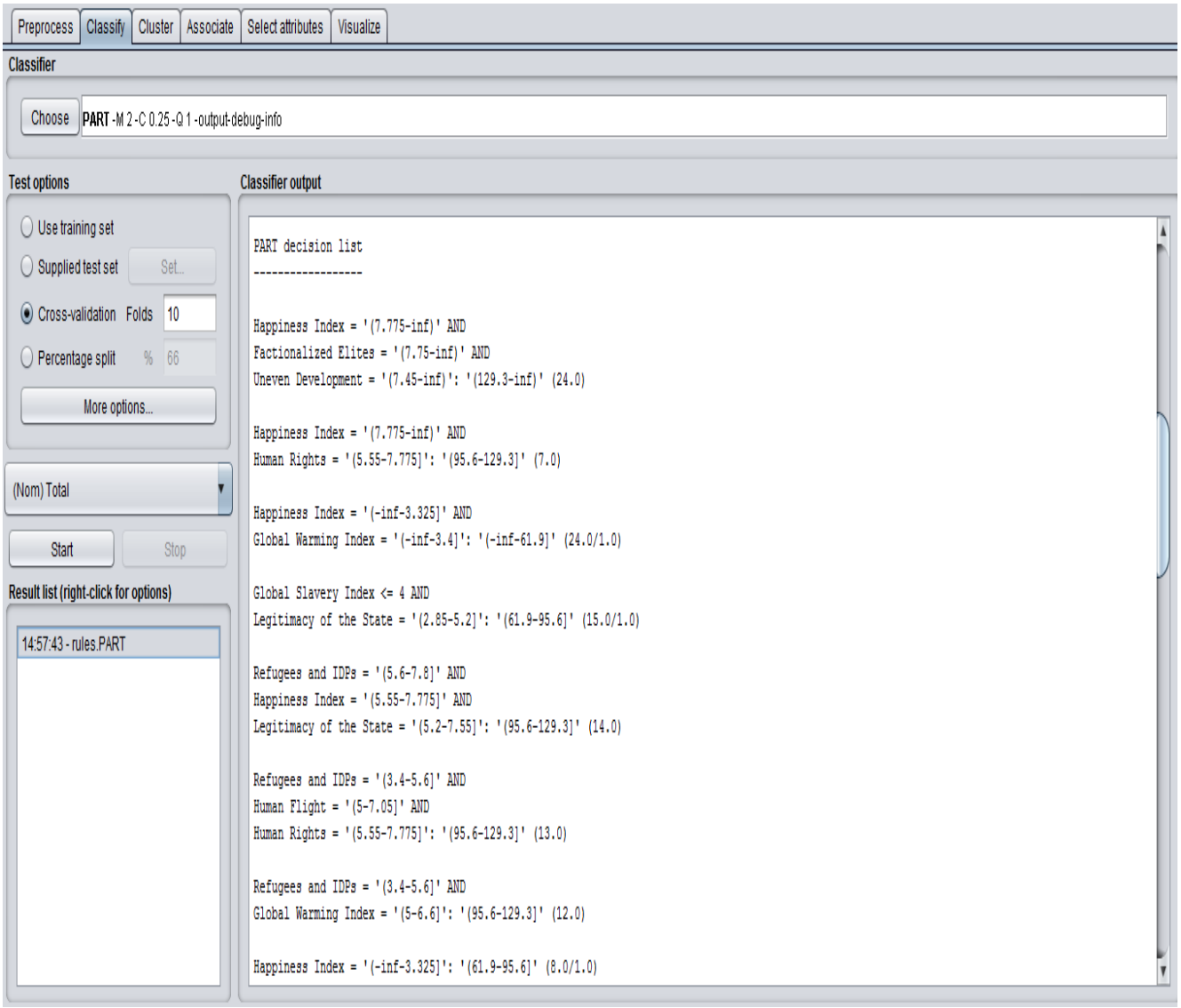
$$\begin{matrix} a & b & c & d \end{matrix}$$
$$\begin{bmatrix} 24 & 1 & 0 & 0 \\ 4 & 32 & 2 & 0 \\ 0 & 1 & 76 & 3 \\ 0 & 0 & 3 & 33 \end{bmatrix}$$
$$\begin{aligned} a &= '(-\inf - 61.9]' \\ b &= '(61.9 - 95.6]' \\ c &= '(95.6 - 129.3]' \\ d &= '(129.3 - \inf)' \end{aligned}$$

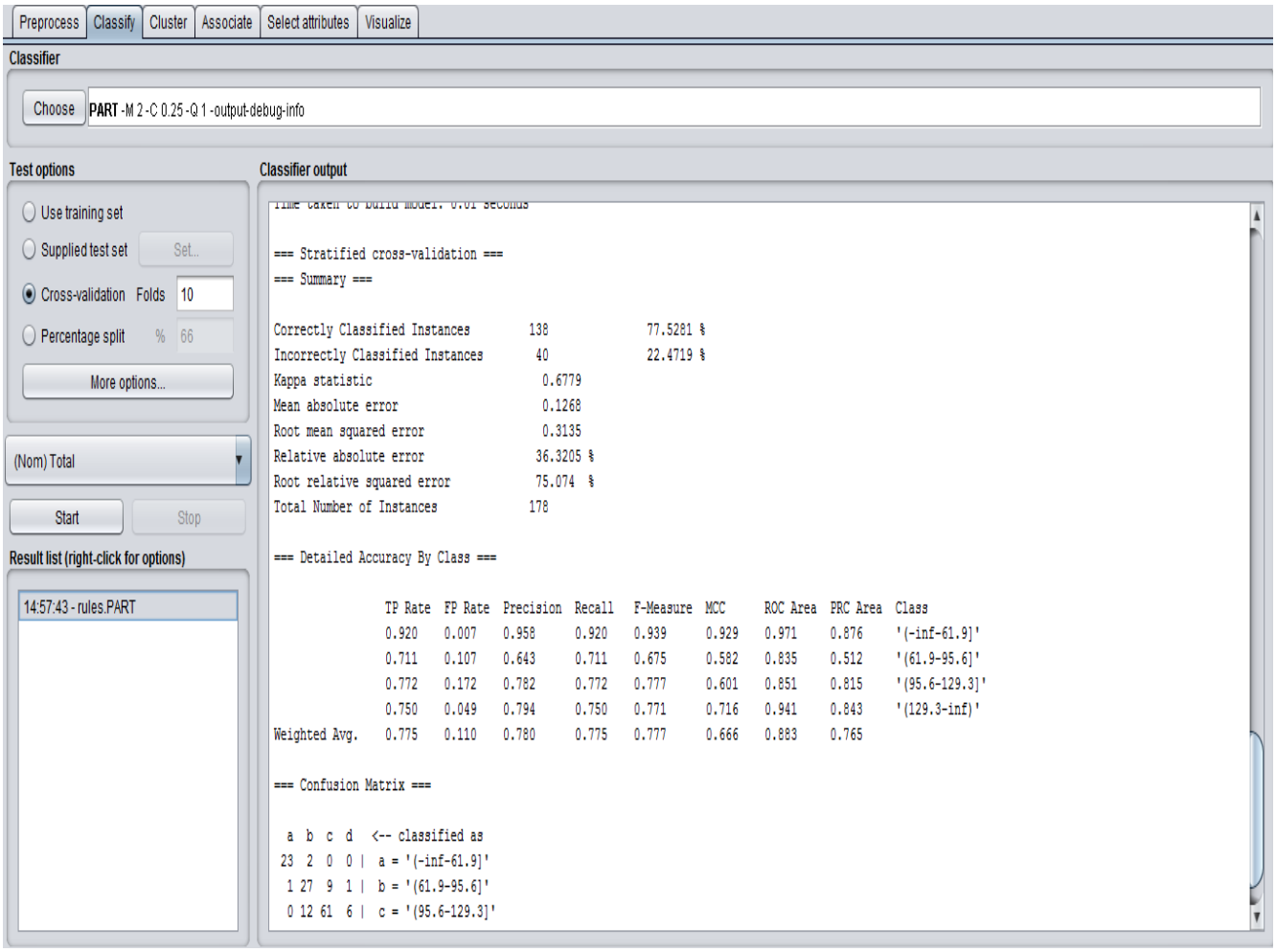
Comparison of Algorithms and Result

Since the percentage of correctly classified instances for Bayes Net, Naïve Bayes, Random Tree, Random Forest and Hoeffding Tree algorithms is 93.2548, 92.1348, 81.4607, 87.0787, 95.5056 respectively. This clearly shows that Hoeffding Tree algorithm is best used to classify as it has high accuracy when compared with other algorithms.

Determining Action Rules

We have determined the action rules by using Weka by selecting the Rules-PART filter as the classifier and run for the data with total as the decision attribute. The rules are logged in a word document and the result screenshot is shown below.




Preprocess
Classify
Cluster
Associate
Select attributes
Visualize
Classifier
Choose
PART -M 2 -C 0.25 -Q 1 -output-debug-info
Test options
Use training set
Supplied test set
Set...
Cross-validation Folds 10
Percentage split % 66
More options...
(Nom) Total
Start
Stop
Result list (right-click for options)
14:57:43 - rules.PART
Classifier output
Time taken to build model: 0.01 seconds
=== Stratified cross-validation ===
=== Summary ===
Correctly Classified Instances 138 77.5281 %
Incorrectly Classified Instances 40 22.4719 %
Kappa statistic 0.6779
Mean absolute error 0.1268
Root mean squared error 0.3135
Relative absolute error 36.3205 %
Root relative squared error 75.074 %
Total Number of Instances 178
=== Detailed Accuracy By Class ===
TP Rate FP Rate Precision Recall F-Measure MCC ROC Area PRC Area Class
0.920 0.007 0.958 0.920 0.939 0.929 0.971 0.876 '(-inf-61.9]'
0.711 0.107 0.643 0.711 0.675 0.582 0.835 0.512 '(61.9-95.6]'
0.772 0.172 0.782 0.772 0.777 0.601 0.851 0.815 '(95.6-129.3]'
0.750 0.049 0.794 0.750 0.771 0.716 0.941 0.843 '(129.3-inf)'
Weighted Avg. 0.775 0.110 0.780 0.775 0.777 0.666 0.883 0.765
=== Confusion Matrix ===
a b c d <-- classified as
23 2 0 0 | a = '(-inf-61.9]'
1 27 9 1 | b = '(61.9-95.6]'
0 12 61 6 | c = '(95.6-129.3]'