



Faculty of Engineering and Technology
Computer Science Department

Artificial intelligence
ENCS 3340

Project 2 report
Machine Learning for Classification

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Section: 3
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Speaker Accent Recognition Dataset:

The Speaker Accent Recognition Dataset contains recordings of speech samples from different speakers, labeled by their respective languages. Each instance in the dataset represents a set of extracted features from a speech sample, and the task is to classify these samples based on the language of the speaker.

❖ Attributes:

- **The parameters (x_1, x_2, \dots, x_{12}):** that describe sounds typically refer to the 12 Mel-frequency cepstral coefficients (MFCCs). These coefficients are widely used in speech and audio processing to capture the short-term power spectrum of sound. Here is a brief description of each parameter:
 1. **x_1 (MFCC1):** Represents the overall energy in the signal, often associated with the loudness or volume of the sound.
 2. **x_2 (MFCC2):** Captures the slope of the spectrum, related to the timbre or quality of the sound.
 3. **x_3 (MFCC3):** Reflects the shape of the spectrum, providing information about the formant frequencies.
 4. **x_4 (MFCC4):** Further refines the spectral shape and captures additional details about the formants.
 5. **x_5 (MFCC5):** Continues to describe the spectral envelope, refining the characterization of the sound.
 6. **x_6 (MFCC6):** Adds more detail to the spectral shape, focusing on higher-order characteristics.
 7. **x_7 (MFCC7):** Captures finer details of the spectral envelope, often associated with subtle changes in timbre.
 8. **x_8 (MFCC8):** Further refines the spectral shape, focusing on higher frequencies.
 9. **x_9 (MFCC9):** Adds more detail to the higher frequency components of the spectrum.
 10. **x_{10} (MFCC10):** Continues to describe the spectral envelope with a focus on higher frequencies.
 11. **x_{11} (MFCC11):** Captures even finer details of the spectral shape, often associated with very subtle characteristics of the sound.
 12. **x_{12} (MFCC12):** Further refines the spectral shape, providing a comprehensive representation of the sound's characteristics.

These coefficients are derived from the logarithm of the power spectrum of the sound signal, followed by a discrete cosine transform (DCT). They are essential in various applications, such as speech recognition, speaker identification, and audio classification, as they effectively represent the key features of the sound.

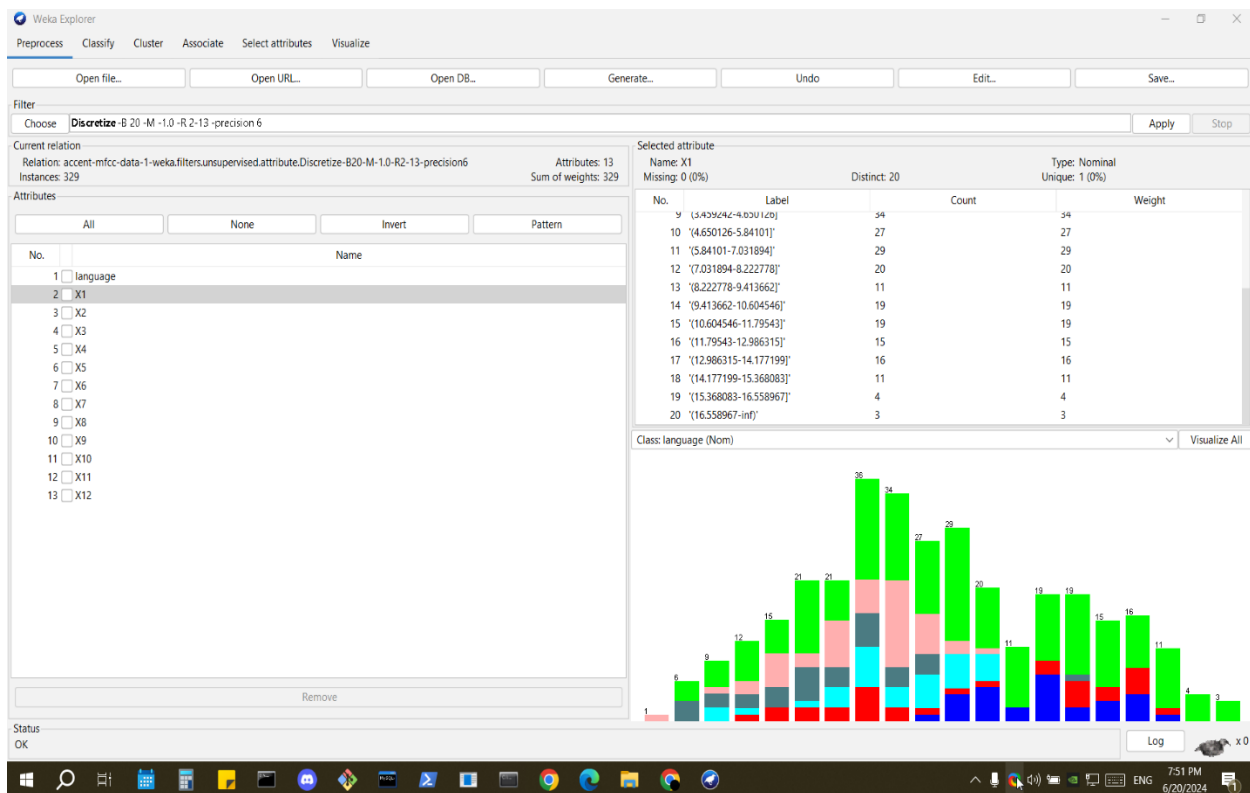
- **Language:** The classification representing the language of the speaker. It is a nominal attribute with the following possible values:
 - ES:** Spanish
 - FR:** French
 - GE:** German
 - IT:** Italian
 - UK:** British English
 - US:** American English

1. Decision Tree:

Test 1:

- Discretized all continuous attributes (X1-X12) to 20 Bins.
- Test is done on 5-fold cross validation.
- No hyper-parameter is changed (default).

➤ Preprocessing:



➤ Classification:

Classifier: J48 -C 0.25 -M 2

Test options:
☐ Use training set
☐ Supplied test set
☒ Cross-validation Folds: 5
☐ Percentage split %: 66
[More options...](#)

(Nom) language: Start Stop

Result list (right-click for options):
 19:55:02 - treesJ48

Classifier output:
 Time taken to build model: 0.01 seconds
 === Stratified cross-validation ===
 === Summary ===
 Correctly Classified Instances 171 51.9757 %
 Incorrectly Classified Instances 158 48.0243 %
 Kappa statistic 0.0986
 Mean absolute error 0.2141
 Root mean squared error 0.3371
 Relative absolute error 91.7357 %
 Root relative squared error 98.5063 %
 Total Number of Instances 329
 === Detailed Accuracy By Class ===

	FP Rate	PP Rate	Precision	Recall	F-Measure	MCC	ROC Area	SRC Area	Class
	0.172	0.013	0.556	0.172	0.263	0.276	0.691	0.244	ES
	0.033	0.020	0.143	0.033	0.054	0.026	0.580	0.128	FR
	0.100	0.007	0.600	0.100	0.171	0.220	0.658	0.176	GE
	0.067	0.000	1.000	0.067	0.125	0.247	0.603	0.203	IT
	0.022	0.014	0.200	0.022	0.040	0.023	0.525	0.153	UK
	0.964	0.966	0.528	0.964	0.682	0.175	0.578	0.586	US
Weighted Avg.	0.520	0.440	0.500	0.520	0.403	0.160	0.590	0.382	

==== Confusion Matrix ====

a	b	c	d	e	f	<-- classified as
5	0	1	0	2	21	a = ES
1	1	0	0	0	28	b = FR
0	0	3	0	0	27	c = GE
0	3	0	2	0	25	d = IT
2	0	1	0	1	41	e = UK
1	3	0	0	2	159	f = US

Status: OK

➤ Result:

==== Confusion Matrix ====

a b c d e f <-- classified as

5 0 1 0 2 21 | a = ES

1 1 0 0 0 28 | b = FR

0 0 3 0 0 27 | c = GE

0 3 0 2 0 25 | d = IT

2 0 1 0 1 41 | e = UK

1 3 0 0 2 159 | f = US

Accuracy: 51.9757 %

Precision: 0.500

Recall: 0.520

F1-score: 0.5098

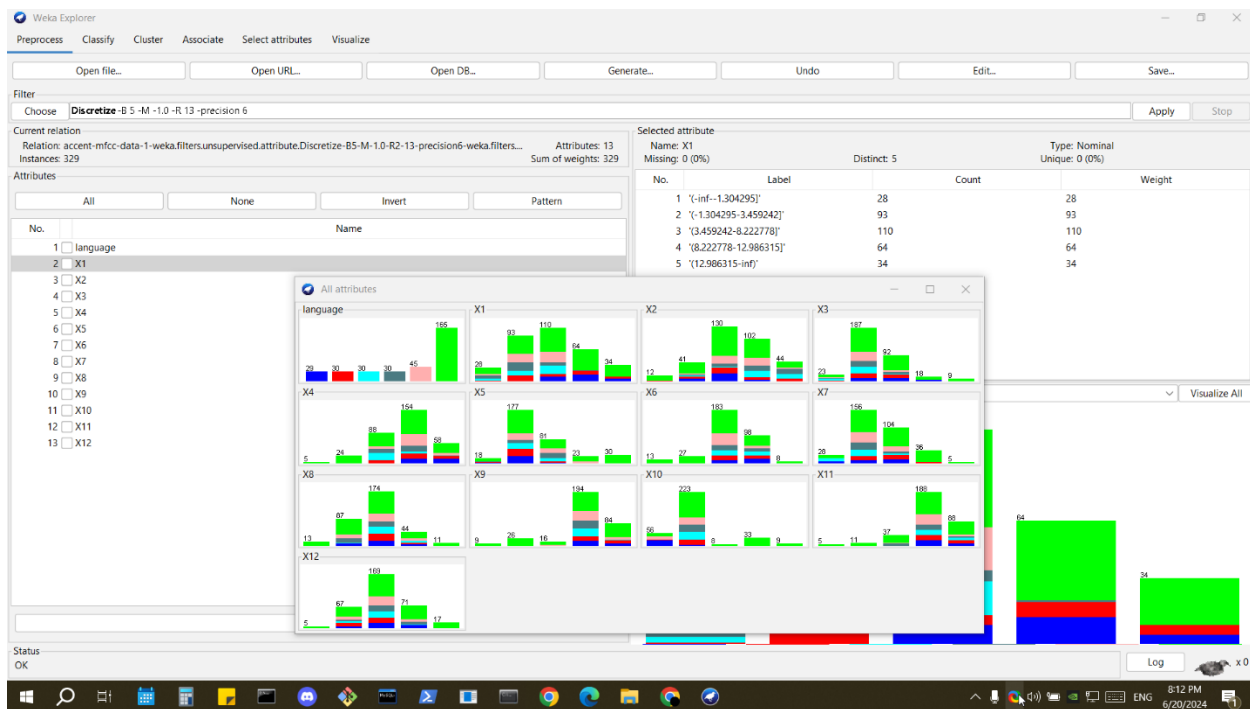
➤ Results Discussion:

Low accuracy (51.98%). Poor classification, especially for classes 'a' and 'f'.

Test 2:

- Discretized all continuous attributes (X1-X12) to 5 Bins.
- Test is done on 5-fold cross validation.
- No hyper-parameter is changed (default).

➤ Preprocessing:



➤ Classification:

Classifier output

Time taken to build model: 0 seconds

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

Correctly Classified Instances	194	58.9666 %
Incorrectly Classified Instances	135	41.0334 %
Kappa statistic	0.4038	
Mean absolute error	0.1561	
Root mean squared error	0.3267	
Relative absolute error	66.9026 %	
Root relative squared error	95.8429 %	
Total Number of Instances	329	

=== Detailed Accuracy By Class ===

	TP Rate	FP Rate	Precision	Recall	F-Measure	ROC Area	PRC Area	Class
0.506	0.060	0.486	0.506	0.531	0.484	0.865	0.443	ES
0.100	0.043	0.188	0.100	0.130	0.076	0.421	0.122	FR
0.433	0.077	0.361	0.433	0.394	0.329	0.785	0.286	GE
0.300	0.050	0.375	0.300	0.333	0.277	0.642	0.247	IT
0.533	0.077	0.522	0.533	0.527	0.452	0.775	0.499	UK
0.776	0.268	0.744	0.776	0.760	0.508	0.797	0.771	US
Weighted Avg.	0.590	0.166	0.572	0.590	0.578	0.421	0.768	0.554

=== Confusion Matrix ===

	a	b	c	d	e	f	<-- classified as
17	1	0	0	5	6		a = ES
3	3	6	3	1	14		b = FR
0	1	13	5	2	9		c = GE
0	3	6	9	2	10		d = IT
5	2	6	3	24	5		e = UK
10	6	5	4	12	128		f = US

➤ Result:

=== Confusion Matrix ===

a b c d e f <-- classified as

17 1 0 0 5 6 | a = ES

3 3 6 3 1 14 | b = FR

0 1 13 5 2 9 | c = GE

0 3 6 9 2 10 | d = IT

5 2 6 3 24 5 | e = UK

10 6 5 4 12 128 | f = US

Accuracy: 58.9666 %

Precision: 0.572

Recall: 0.590

F1-score: 0.58086

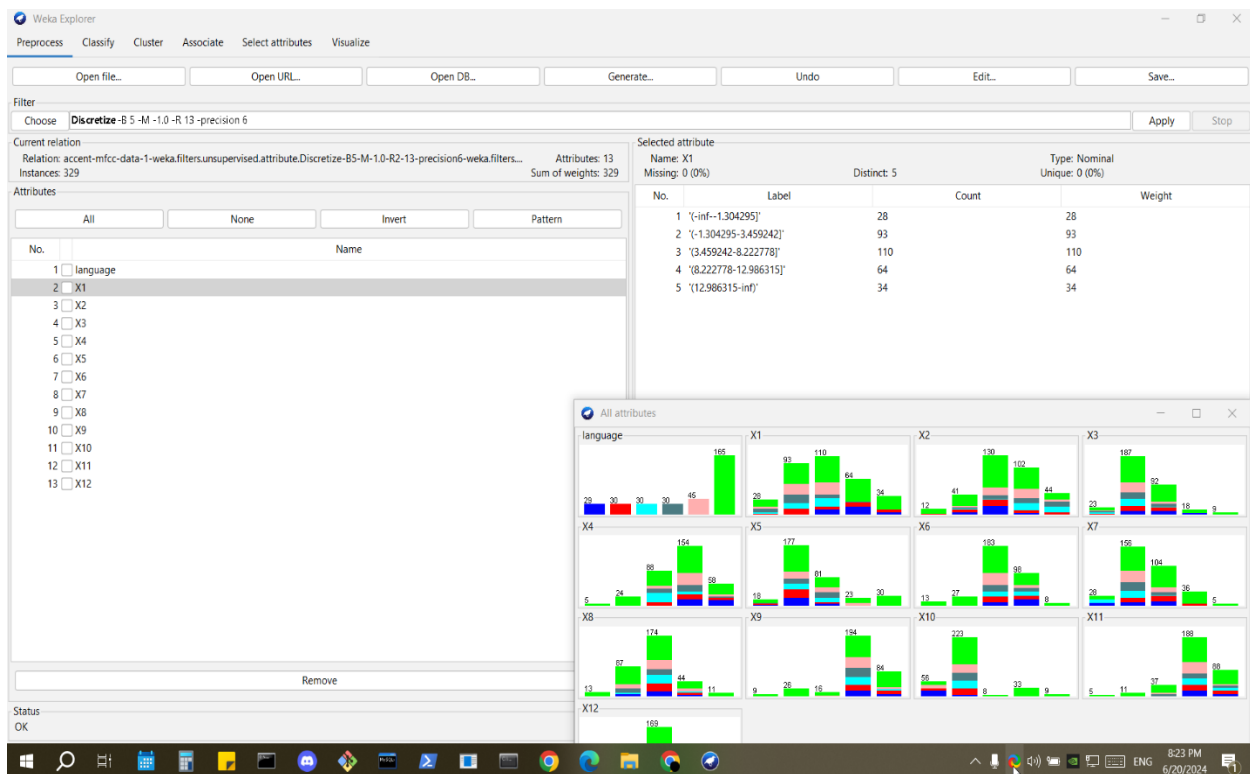
➤ Results Discussion:

Slight improvement (58.97%) with better balance across classes.

Test 3:

- Discretized all continuous attributes (X1-X12) to 5 Bins.
- Test is done on 5-fold cross validation.
- Hyper-parameter: (confidence factor) is sat to (0.55) according to many tests done to find a good value for it.

➤ Preprocessing:



➤ Classification:

Weka Explorer

Preprocess Classify Cluster Associate Select attributes Visualize

Classifier

Choose J48-C 0.55-M 2

Test options

☐ Use training set

☐ Supplied test set Set...

☒ Cross-validation Folds 5

☐ Percentage split % 66

More options...

(Nom) language

Start Stop

Result list (right-click for options)

20:11:14 - trees.J48

20:15:41 - trees.J48

20:15:55 - trees.J48

20:16:05 - trees.J48

20:16:22 - trees.J48

20:17:58 - trees.J48

20:18:05 - trees.J48

20:18:15 - trees.J48

20:18:25 - trees.J48

20:18:43 - trees.J48

20:18:58 - trees.J48

20:19:11 - trees.J48

20:19:30 - trees.J48

20:19:41 - trees.J48

20:19:49 - trees.J48

20:19:58 - trees.J48

Classifier output

Time taken to build model: 0.25 seconds

=== Stratified cross-validation ===

=== Summary ===

Correctly Classified Instances	199	60.4863 %
Incorrectly Classified Instances	130	39.5137 %
Kappa statistic	0.4445	
Mean absolute error	0.1394	
Root mean squared error	0.3242	
Relative absolute error	59.7335 %	
Root relative squared error	95.1044 %	
Total Number of Instances	329	

=== Detailed Accuracy By Class ===

	TP Rate	FP Rate	Precision	Recall	F-Measure	MCG	ROC Area	PRC Area	Class
0.690	0.057	0.541	0.690	0.606	0.646	0.568	0.879	0.474	ES
0.300	0.104	0.225	0.300	0.257	0.173	0.690	0.174		FR
0.367	0.064	0.367	0.367	0.367	0.367	0.303	0.754	0.278	GE
0.433	0.043	0.500	0.433	0.433	0.464	0.416	0.704	0.306	IT
0.511	0.067	0.548	0.511	0.525	0.457	0.768	0.486	0.486	UK
0.745	0.189	0.799	0.745	0.771	0.558	0.816	0.783	0.783	US
Weighted Avg.	0.605	0.128	0.623	0.605	0.612	0.474	0.788	0.570	

=== Confusion Matrix ===

	a	b	c	d	e	f	<-- classified as
20	1	0	0	4	4		a = ES
3	9	5	3	0	10		b = FR
0	7	11	4	3	5		c = GE
0	6	3	13	1	7		d = IT
5	3	6	3	23	5		e = UK
9	14	5	3	11	123		f = US

Status OK

Log

8:23 PM 6/20/2024

➤ Result:

=== Confusion Matrix ===

a b c d e f <-- classified as

20 1 0 0 4 4 | a = ES

3 9 5 3 0 10 | b = FR

0 7 11 4 3 5 | c = GE

0 6 3 13 1 7 | d = IT

5 3 6 3 23 5 | e = UK

9 14 5 3 11 123 | f = US

Accuracy: 60.4868 %

Precision: 0.623

Recall: 0.605

F1-score: 0.613868

➤ Results Discussion:

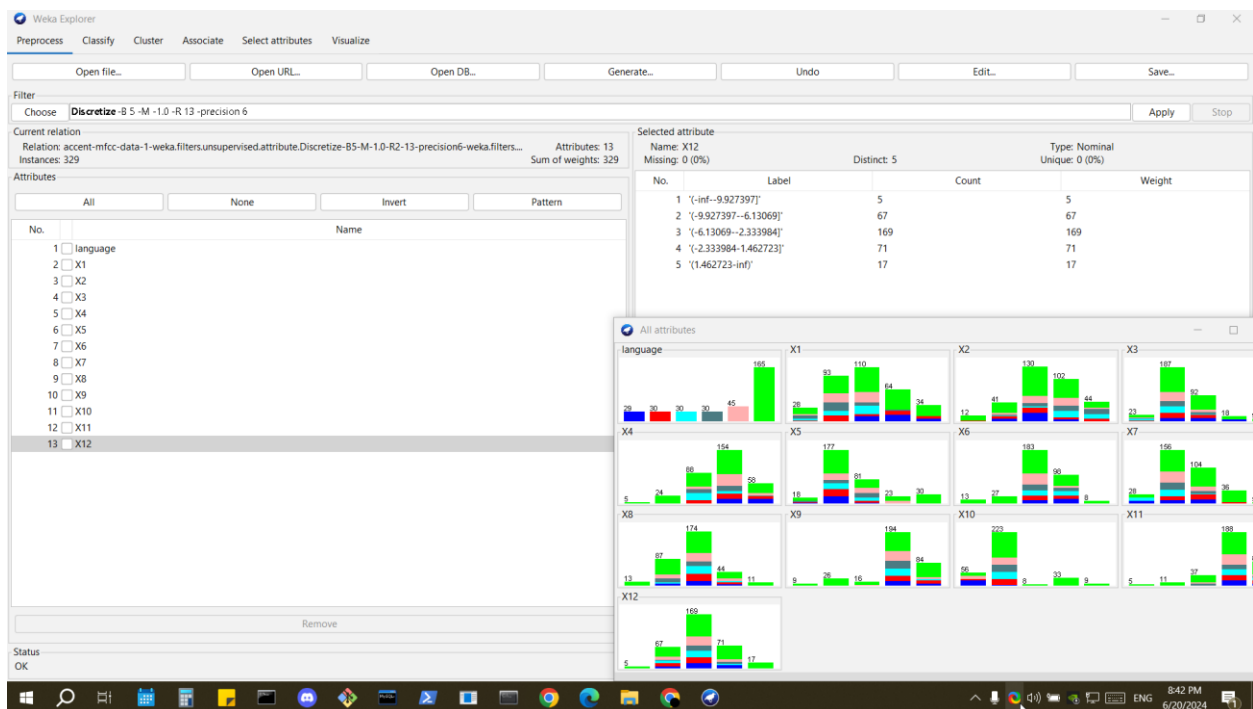
Best accuracy (60.49%) among tests with improved precision and recall.

2. Naive Bias:

Test 1:

- Discretized all continuous attributes (X1-X12) to 20 bins.
- Test is done on 5-fold cross validation.
- No hyper-parameter is changed (default).

➤ Preprocessing:



➤ Classification:

Classifier output

Time taken to build model: 0 seconds

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

Correctly Classified Instances	192	58.3587 %
Incorrectly Classified Instances	137	41.6413 %
Kappa statistic	0.3949	
Mean absolute error	0.168	
Root mean squared error	0.3134	
Relative absolute error	71.9825 %	
Root relative squared error	91.9315 %	
Total Number of Instances	329	

=== Detailed Accuracy By Class ===

	TP Rate	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
	0.690	0.030	0.690	0.690	0.690	0.660	0.946	0.726	ES
	0.233	0.033	0.412	0.233	0.298	0.260	0.814	0.348	FR
	0.633	0.067	0.487	0.633	0.551	0.504	0.901	0.511	GE
	0.133	0.047	0.222	0.133	0.167	0.110	0.790	0.273	IT
	0.511	0.113	0.418	0.511	0.460	0.367	0.780	0.403	UK
	0.721	0.317	0.656	0.721	0.708	0.404	0.778	0.771	US
Weighted Avg.	0.584	0.150	0.569	0.584	0.572	0.391	0.809	0.609	

=== Confusion Matrix ===

	a	b	c	d	e	f	<-- classified as
20	1	0	0	3	5		a = ES
3	7	1	4	4	11		b = FR
0	0	19	1	3	7		c = GE
0	0	5	4	6	15		d = IT
0	0	3	5	23	14		e = UK
6	9	11	4	16	119		f = US

➤ Result:

=== Confusion Matrix ===

a b c d e f <-- classified as

20 1 0 0 3 5 | a = ES

3 7 1 4 4 11 | b = FR

0 0 19 1 3 7 | c = GE

0 0 5 4 6 15 | d = IT

0 0 3 5 23 14 | e = UK

6 9 11 4 16 119 | f = US

Accuracy: 58.3587 %

Precision: 0.569

Recall: 0.584

F1-score: 0.5764

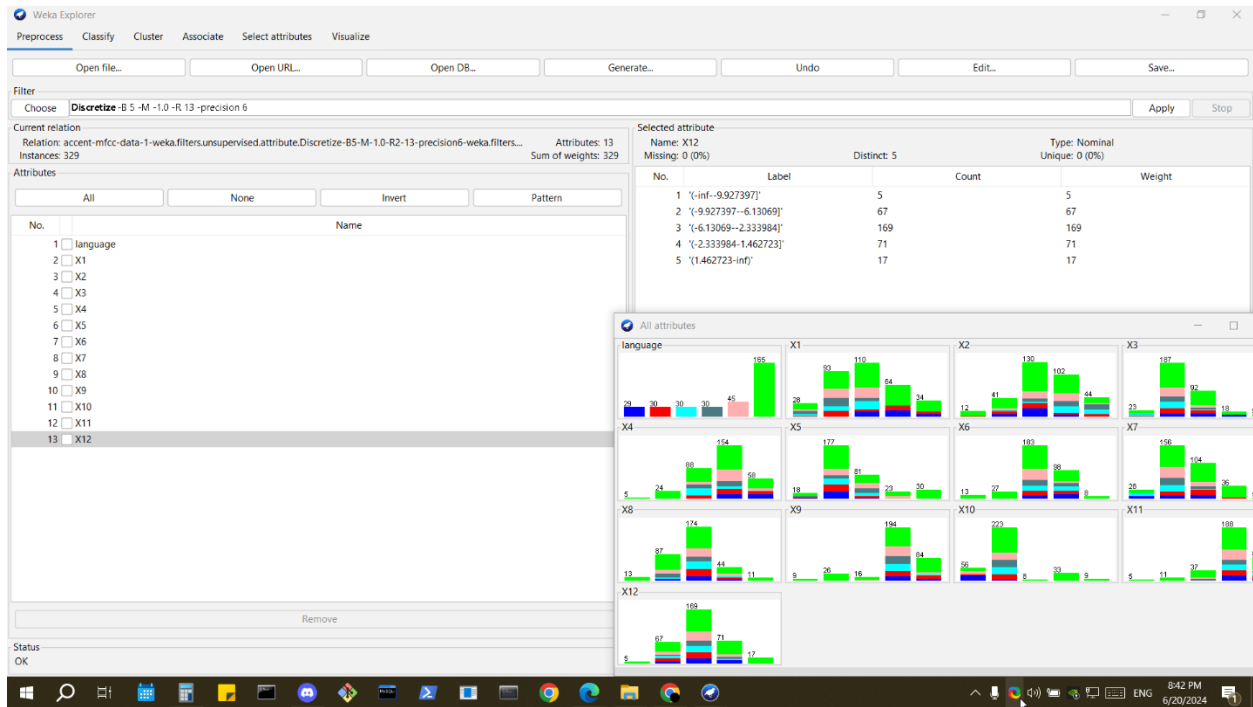
➤ Results Discussion:

Moderate accuracy (58.36%), fair precision, and recall.

Test 2:

- Discretized all continuous attributes (X1-X12) to 5 bins.
- Test is done on 5-fold cross validation.
- No hyper-parameter is changed (default).

➤ Preprocessing:



➤ Classification:

Classifier output

Time taken to build model: 0 seconds

```

=== Stratified cross-validation ===
=== Summary ===
Correctly Classified Instances      179           54.4073 %
Incorrectly Classified Instances    150           45.5927 %
Kappa statistic                    0.4031
Mean absolute error                 0.1696
Root mean squared error             0.3077
Relative absolute error             72.673 %
Root relative squared error         90.2592 %
Total Number of Instances          329

=== Detailed Accuracy By Class ===

```

	TP Rate	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
	0.759	0.070	0.512	0.759	0.611	0.579	0.953	0.712	ES
	0.133	0.067	0.167	0.133	0.148	0.074	0.705	0.180	FR
	0.700	0.080	0.467	0.700	0.560	0.519	0.901	0.598	GE
	0.400	0.040	0.500	0.400	0.444	0.398	0.877	0.432	IT
	0.689	0.194	0.360	0.689	0.473	0.387	0.861	0.539	UK
	0.539	0.110	0.832	0.539	0.654	0.459	0.828	0.851	US
Weighted Avg.	0.544	0.105	0.615	0.544	0.552	0.424	0.843	0.674	

```

=== Confusion Matrix ===
 a b c d e f <-- classified as
22 2 0 0 3 2 | a = ES
 5 4 8 2 5 6 | b = FR
 0 1 21 3 3 2 | c = GE
 0 0 5 12 8 5 | d = IT
 2 1 5 3 31 3 | e = UK
14 16 6 4 36 89 | f = US

```

➤ Result:

=== Confusion Matrix ===

a b c d e f <-- classified as

22 2 0 0 3 2 | a = ES

5 4 8 2 5 6 | b = FR

0 1 21 3 3 2 | c = GE

0 0 5 12 8 5 | d = IT

2 1 5 3 31 3 | e = UK

14 16 6 4 36 89 | f = US

Accuracy: 54.4073%

Precision: 0.615

Recall: 0.544

F1-score: 0.522

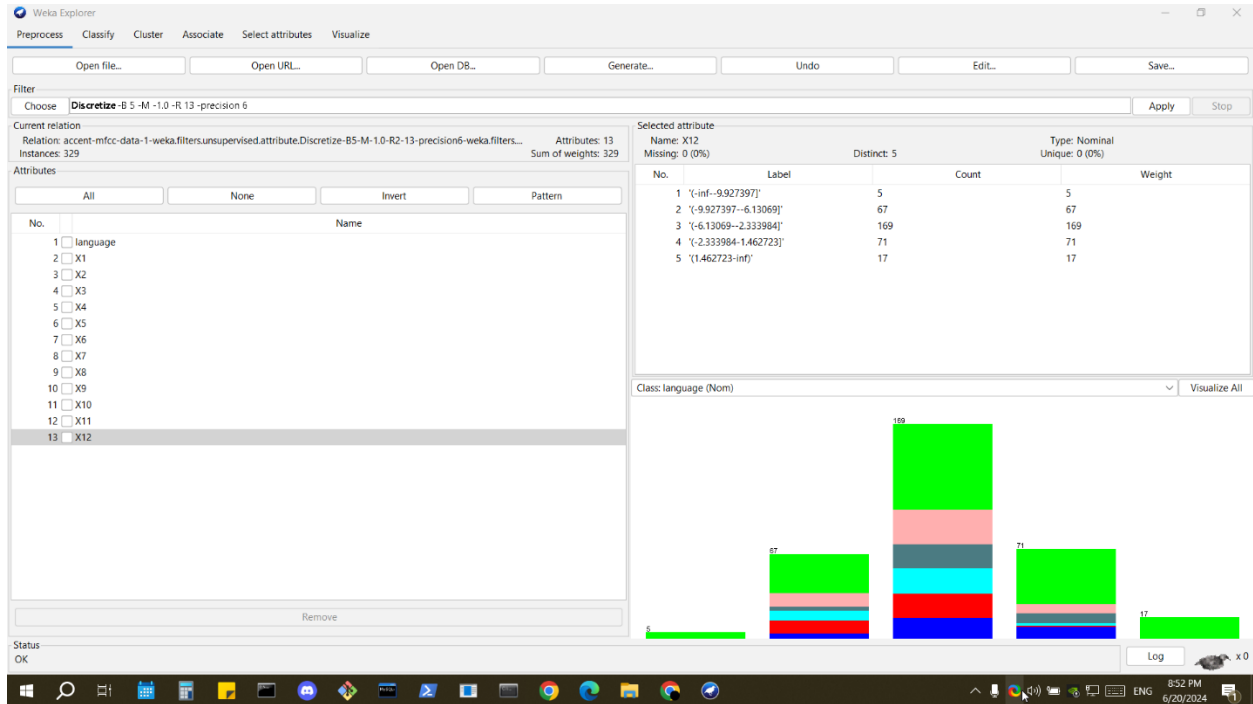
➤ Results Discussion:

Reduced accuracy (54.41%). Balanced performance with a lower F1-score.

Test 3:

- Discretized all continuous attributes (X1-X12) to 5 bins.
- Test is done on 5-fold cross validation.
- Hyper-parameter: (batch size) is set to (150) according to many tests done to find a good value for it.

➤ Preprocessing:



➤ Classification:

The screenshot shows the Weka Explorer interface with the NaiveBayes classifier selected. The 'Test options' section shows 'Cross-validation' with 'Folds' set to 5 and 'Percentage split' set to 66. The 'Classifier output' section displays the following results:

Time taken to build model: 0 seconds

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

Metric	Value	Percentage
Correctly Classified Instances	179	54.4073 %
Incorrectly Classified Instances	150	45.5927 %
Kappa statistic	0.4031	
Mean absolute error	0.1696	
Root mean squared error	0.3077	
Relative absolute error	72.673 %	
Root relative squared error	90.2592 %	
Total Number of Instances	329	

=== Detailed Accuracy By Class ===

	TP Rate	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
204258 - bytes.NaiveBayes	0.759	0.070	0.512	0.759	0.611	0.579	0.953	0.712	ES
204550 - bytes.NaiveBayes	0.133	0.067	0.167	0.133	0.148	0.074	0.705	0.180	FR
204556 - bytes.NaiveBayes	0.700	0.080	0.467	0.700	0.560	0.519	0.901	0.598	GE
204603 - bytes.NaiveBayes	0.400	0.040	0.500	0.400	0.444	0.398	0.877	0.432	IT
204609 - bytes.NaiveBayes	0.689	0.194	0.360	0.689	0.473	0.387	0.861	0.539	UK
204610 - bytes.NaiveBayes	0.539	0.110	0.832	0.539	0.654	0.459	0.828	0.851	US
Weighted Avg.	0.544	0.105	0.615	0.544	0.552	0.424	0.843	0.674	

=== Confusion Matrix ===

a	b	c	d	e	f	<-- classified as
22	2	0	0	3	2	a = ES
5	4	8	2	5	6	b = FR
0	1	21	3	3	2	c = GE
0	0	5	12	8	5	d = IT
2	1	5	3	31	3	e = UK
14	16	6	4	36	89	f = US

➤ Result:

=== Confusion Matrix ===

a b c d e f <-- classified as

22 2 0 0 3 2 | a = ES

5 4 8 2 5 6 | b = FR

0 1 21 3 3 2 | c = GE

0 0 5 12 8 5 | d = IT

2 1 5 3 31 3 | e = UK

14 16 6 4 36 89 | f = US

Accuracy: 54.4073%

Precision: 0.615

Recall: 0.544

F1-score: 0.522

➤ Results Discussion:

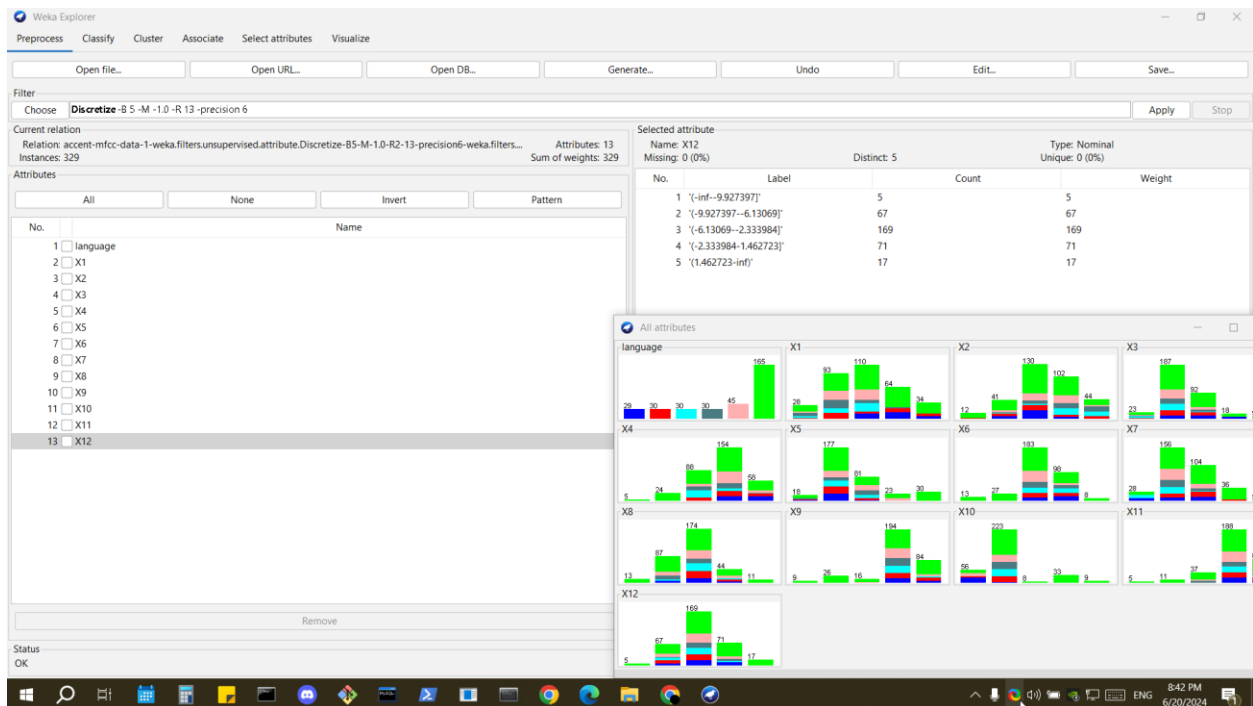
Identical results to Test 2, indicating batch size adjustment had no effect.

3. MLP

Test 1:

- Discretized all continuous attributes (X1-X12) to 20 bins.
- Test is done on 5-fold cross validation.
- No hyper-parameter is changed (default).

➤ Preprocessing:



➤ Classification:

The screenshot shows the Weka Explorer interface with the MultilayerPerceptron classifier selected. The 'Test options' section on the left shows 'Cross-validation' with 'Folds' set to 5. The 'Classifier output' section on the right displays the following results:

Time taken to build model: 53.68 seconds

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

==== Summary ====

Metric	Value
Correctly Classified Instances	202
Incorrectly Classified Instances	127
Kappa statistic	0.4409
Mean absolute error	0.138
Root mean squared error	0.3205
Relative absolute error	59.1489 %
Root relative squared error	94.0288 %
Total Number of Instances	329

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

FP Rate	PP Rate	Precision	Recall	F-Measure	MCC	ROC Area	SRC Area	Class
0.517	0.033	0.600	0.517	0.556	0.518	0.943	0.733	ES
0.433	0.060	0.419	0.433	0.426	0.368	0.820	0.426	FR
0.600	0.057	0.514	0.600	0.554	0.507	0.914	0.428	GE
0.300	0.064	0.321	0.300	0.310	0.244	0.835	0.373	IT
0.467	0.063	0.538	0.467	0.500	0.429	0.814	0.541	UK
0.764	0.274	0.737	0.764	0.750	0.490	0.803	0.822	US
Weighted Avg.	0.614	0.166	0.611	0.614	0.611	0.452	0.832	

==== Confusion Matrix ====

a	b	c	d	e	f	<-- classified as
15	2	0	0	4	8	a = ES
1	13	1	6	1	8	b = FR
0	2	18	1	1	8	c = GE
0	1	3	9	5	12	d = IT
3	2	4	6	21	9	e = UK
6	11	9	6	7	126	f = US

➤ Result:

==== Confusion Matrix ====

a b c d e f <-- classified as

15 2 0 0 4 8 | a = ES

1 13 1 6 1 8 | b = FR

0 2 18 1 1 8 | c = GE

0 1 3 9 5 12 | d = IT

3 2 4 6 21 9 | e = UK

6 11 9 6 7 126 | f = US

Accuracy: 61.3982 %

Precision: 0.611

Recall: 0.614

F1-score: 0.611

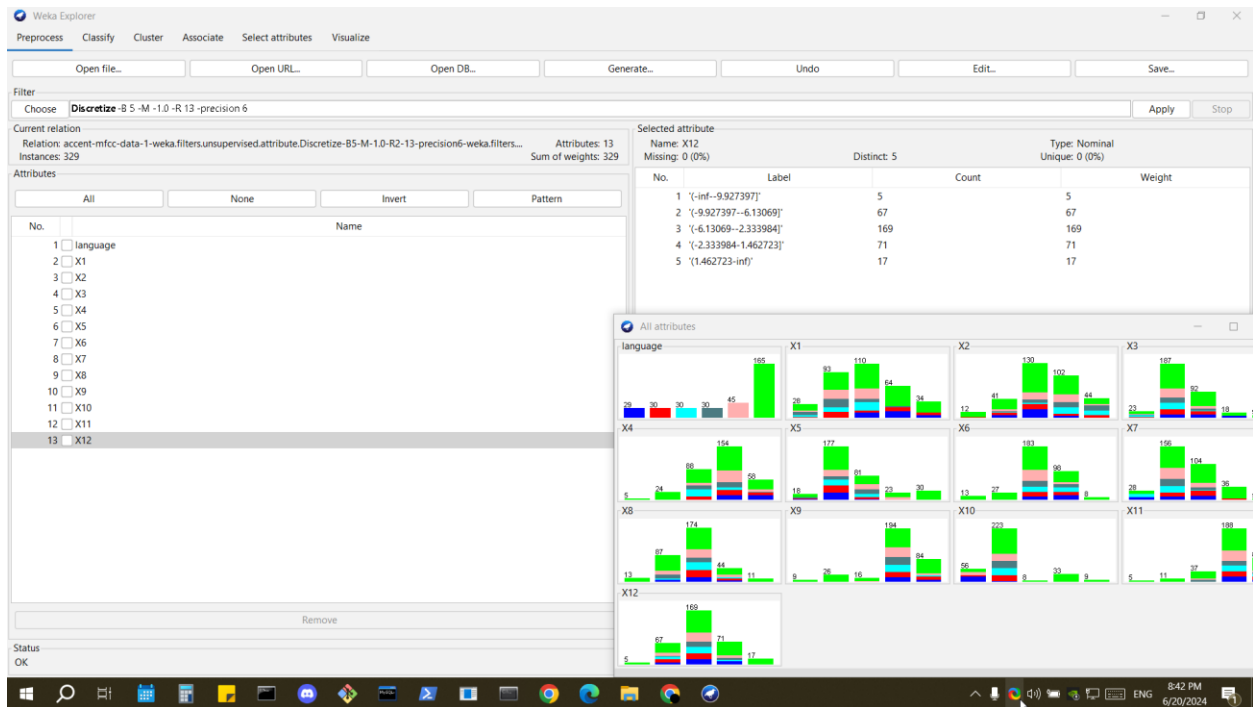
➤ Results Discussion:

Good accuracy (61.40%), balanced precision, and recall.

Test 2:

- Discretized all continuous attributes (X1-X12) to 5 bins.
- Test is done on 5-fold cross validation.
- No hyper-parameter is changed (default).

➤ Preprocessing:



➤ Classification:

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

Time taken to build model: 4.05 seconds

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

==== Summary ====

Metric	Value	Percentage
Correctly Classified Instances	213	64.7416 %
Incorrectly Classified Instances	116	35.2584 %
Kappa statistic	0.4932	
Mean absolute error	0.1276	
Root mean squared error	0.3044	
Relative absolute error	54.6872 %	
Root relative squared error	89.2596 %	
Total Number of Instances	329	

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

TP Rate	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.621	0.037	0.621	0.621	0.621	0.584	0.959	0.655	ES
0.333	0.040	0.455	0.333	0.385	0.338	0.802	0.374	FR
0.533	0.067	0.444	0.533	0.485	0.430	0.861	0.407	GE
0.533	0.047	0.533	0.533	0.533	0.487	0.890	0.450	IT
0.489	0.085	0.478	0.489	0.484	0.401	0.853	0.538	UK
0.794	0.213	0.769	0.794	0.792	0.561	0.873	0.892	US
Weighted Avg.	0.647	0.136	0.647	0.646	0.512	0.872	0.691	

==== Confusion Matrix ====

a	b	c	d	e	f	<-- classified as
18	0	0	0	3	8	a = ES
2	10	6	0	2	10	b = FR
0	4	16	5	1	4	c = GE
0	1	4	16	5	4	d = IT
2	3	3	6	22	9	e = UK
7	4	7	3	13	131	f = US

➤ Result:

==== Confusion Matrix ====

a b c d e f <-- classified as

18 0 0 0 3 8 | a = ES

2 10 6 0 2 10 | b = FR

0 4 16 5 1 4 | c = GE

0 1 4 16 5 4 | d = IT

2 3 3 6 22 9 | e = UK

7 4 7 3 13 131 | f = US

Accuracy: 64.7416 %

Precision: 0.647

Recall: 0.647

F1-score: 0.646

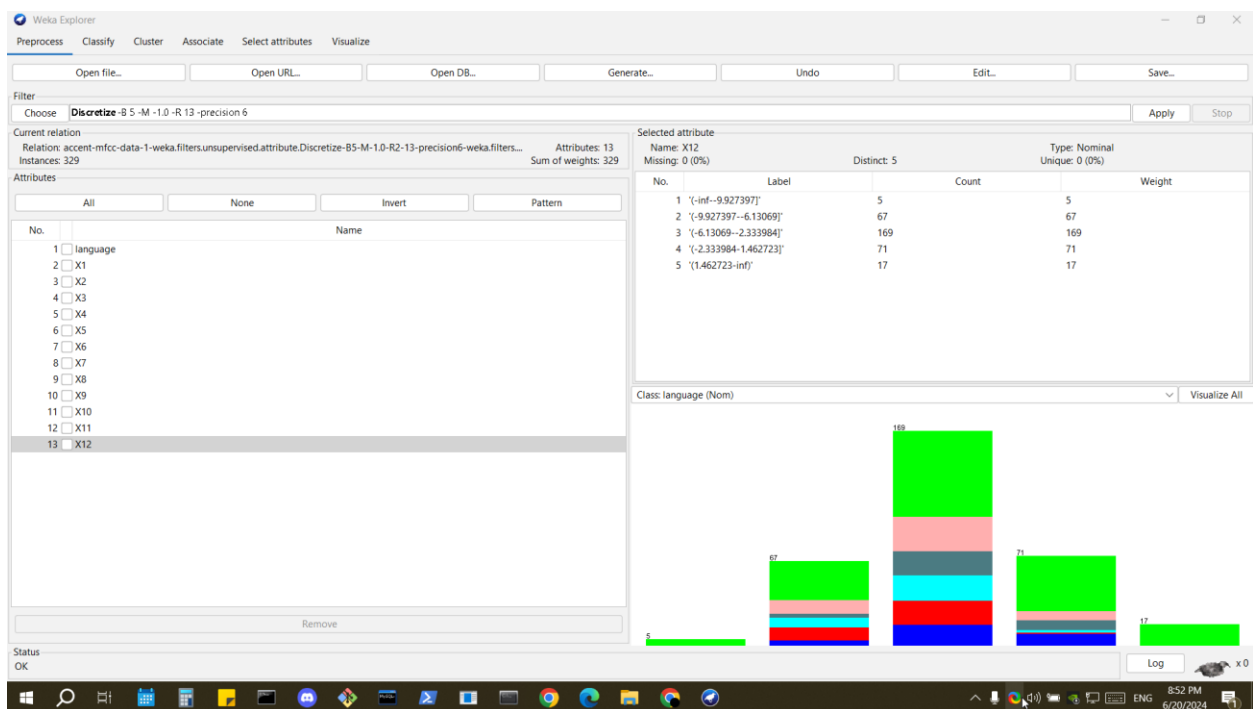
➤ Results Discussion:

Improved accuracy (64.74%) with consistent classification across classes.

Test 3:

- Discretized all continuous attributes (X1-X12) to 5 bins.
- Test is done on 5-fold cross validation.
- Hyper-parameter: (learning rate) is sat to (0.2) according to many tests done to find a good value for it.

➤ Preprocessing:



➤ Classification:

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

Time taken to build model: 4.03 seconds

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

==== Summary ====

Metric	Value
Correctly Classified Instances	218
Incorrectly Classified Instances	111
Kappa statistic	0.5133
Mean absolute error	0.127
Root mean squared error	0.3038
Relative absolute error	54.417 %
Root relative squared error	89.1224 %
Total Number of Instances	329

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

	TP Rate	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0.655	0.037	0.633	0.455	0.444	0.409	0.955	0.638		ES
0.300	0.067	0.310	0.300	0.305	0.297	0.758	0.274		FR
0.533	0.074	0.421	0.533	0.471	0.414	0.845	0.454		GE
0.467	0.040	0.538	0.467	0.500	0.455	0.872	0.420		IT
0.511	0.049	0.622	0.511	0.561	0.502	0.885	0.565		UK
0.830	0.195	0.811	0.830	0.820	0.635	0.877	0.897		US
Weighted Avg.	0.663	0.124	0.663	0.663	0.661	0.542	0.871	0.688	

==== Confusion Matrix ====

	a	b	c	d	e	f	<-- classified as
19	4	0	0	1	5		a = ES
4	9	6	1	1	9		b = FR
0	5	16	3	2	4		c = GE
0	2	7	14	2	5		d = IT
1	2	4	6	23	9		e = UK
6	7	5	2	8	137		f = US

➤ Result:

==== Confusion Matrix ====

a b c d e f <-- classified as

19 4 0 0 1 5 | a = ES

4 9 6 1 1 9 | b = FR

0 5 16 3 2 4 | c = GE

0 2 7 14 2 5 | d = IT

1 2 4 6 23 9 | e = UK

6 7 5 2 8 137 | f = US

Accuracy: 66.2614 %

Precision: 0.663

Recall: 0.663

F1-score: 0.661

➤ Results Discussion:

Best performance (66.26%) with high precision and recall.

❖ Changed Hyper Parameters:

- **Confidence Factor in Decision Tree:**

The confidence factor in a decision tree controls the extent of pruning during the training process. A lower confidence factor leads to more aggressive pruning, reducing overfitting but possibly underfitting the data. A higher confidence factor results in less pruning, capturing more data details but increasing the risk of overfitting.

- **Batch Size in Naïve:**

Bayes Batch size in Naive Bayes, though not commonly referenced, can affect the efficiency of processing large datasets. Using larger batch sizes can make the training process more efficient by reducing the number of updates to model parameters, while smaller batch sizes can lead to more frequent updates, which might be beneficial for capturing data variability but could be computationally expensive.

✚ when changing the batch size does not affect the learning process, this means current training setup and data are well-balanced, leading to consistent model performance.

- **Learning Rate in MLP:**

The learning rate in a Multi-Layer Perceptron (MLP) determines the size of the steps taken during gradient descent optimization. A high learning rate can speed up learning but may cause the model to overshoot minima, leading to instability. A low learning rate ensures stable convergence but can make the training process slow and prone to getting stuck in local minima.

❖ Summary Comparison

- **Decision Tree:**

Best accuracy with 5 bins and confidence factor adjustment (Test 3: 60.49%).

- **Naive Bayes:**

Moderate performance, best with 20 bins (Test 1: 58.36%).

- **MLP:**

Overall highest accuracy and balanced performance (Test 3: 66.26%).

In summary, MLP outperforms both Decision Tree and Naive Bayes, particularly with hyper-parameter tuning. Decision Tree shows improvement with discretization and confidence factor adjustments, while Naive Bayes performs moderately well but shows limited sensitivity to hyper-parameter changes.