ISSN 2347 - 3983
Volume 8. No. 7, July 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter22872020.pdf
https://doi.org/10.30534/ijeter/2020/22872020

Classification of Immature and Mature Coffee Beans Using RGB Values and Machine Learning Algorithms

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ABSTRACT

The practice of coffee farmers to harvest all coffee cherries when 75 % of it are full red in a coffee tree gave rise to immature coffee beans. Immature coffee beans are green and yellow coffee cherries which were harvested earlier before they turn fully red, in order to reduce the operating cost of the coffee farmers. This practice greatly lowers the grade of coffee. Visually immature and mature coffee beans are different. Immature coffee beans are darker in color. When they are mixed, it will be very difficult to distinguish one from the other by visual inspection. This paper is about using image processing to extract RGB color features of the mature and immature coffee beans and used the extracted RGB values for classification using the 23 machine learning classifiers of Matlab's Classification Learner App. The best in terms of accuracy and speed in training is the Quadratic Support Vector Machine which has a value of 94 % and 0.62 seconds respectively.

Key words : Immature coffee beans; Mature coffee beans; MATLAB Classification Learner App; RGB values.

1. INTRODUCTION

Coffee is one of the world's most important food commodities[1]. Among all world commodities it is second to crude oil in importance[2]. Coffee is being produced and the main agricultural export product of almost sixty tropical and sub-tropical countries[3]. Quality of coffee beans are evaluated using many criteria among which are size, color , shape, roast potential , flavor or cup quality and the presence of defects[4]. The presence of defects affect the quality of coffee and is associated with harvesting and pre-processing procedures[5]. The different types of coffee bean defects have been discussed in the Department of Agriculture of the Philippines in the Philippine National Standards for Green
Coffee Bean Specifications. According to this standards, there are nine types of defects namely black beans, infested beans, broken beans, immature beans, husk fragments, fermented or sour beans, admixture and foreign matter [6].Based on color, if the coffee bean is greenish, grayish or spongy white, the coffee bean is immature . Immature coffee beans is a result of harvesting coffee fruit even though they are still green or yellow color instead of full ripe red color. One batch harvesting were done because it saves time wherein all coffee cherries are harvested at one time when 75% were red, instead of waiting for green and yellow fruit to turn full red[7]. Green , yellow and red coffee fruits when dried are almost impossible to differentiate visually but the major drawback is the quality or grade of a batch of coffee beans are greatly downgraded because of the presence of immature beans[8].

The common procedure to separate the defective coffee beans is by manual inspection and picking and separating the defective beans. This method is time consuming and is subjective, because it is dependent on the conditions of the person performing the defect selection[9]. Manual inspection systems is based on human judgement and may vary from one person to another, even though both persons are regarded as experts[10]. The objective of this paper is to automate the classification of mature and immature coffee beans using image processing and machine learning algorithms. Image processing is an effective instrument in extracting features of an object [11-30] and machine learning algorithms are efficient tools in discriminating object using the extracted features[9]. The combine image processing and machine learning approach of classification has been tested and found effective in terms of high accuracy in a number of studies [31-32].

2. METHODOLOGY

Coffee beans from harvest season of January to March 2019 were used in this study. There are two coffee bean groups used, the first group are the mature coffee beans which are the fully red coffee cherries picked from the Robusta coffee tree. The second group are the immature coffee beans composed of green and yellow coffee cherries picked from the same coffee tree. Both groups were dried

under the sun for the same duration in different containers. After drying the husk of the coffee beans were removed and stored in a cool dry place. After a year of storage , the taking of images and feature extraction was done on March 2020. Figure 1 shows the coffee bean samples used in this study which are composed of green, yellow and red beans.

Figure 1: Immature and Mature Coffee Beans

In Figure 1 , the first four columns are dried immature beans and the last two columns are mature beans.

B. Feature Extraction

It was observed that the mature and immature coffee beans differ in terms of color visually. The researcher extracted the RGB features of the two bean groups to prove whether they can be differentiated using image processing and machine learning classifiers. A total of 100 mature beans and 100 immature beans were used in the study. The coffee beans were placed in panel board with white background and the images were taken by a A4tech PK -835G webcam, situated directly above the coffee beans at a height of 13.5 cms. For lighting , a two pieces of 3 inch LED strips were put at the two sides of the camera at a distance of 2 inches. The images were saved in a computer and the RGB features were extracted using a python image processing program as shown in Figure 2.

```
#rgb
frame_cpy = frame.copy()
h2,w2,d2 = frame_cpy.shape
_mask = np.zeros((h2,w2), np.uint8)
cv2.drawContours(_mask,[box],-1,(255,255,255),-1)
average_bgr = cv2.mean(frame_cpy,mask = _mask)
#b
ave_b = average_bgr[0]


#r
ave_g = average_bgr[1]
#g
ave_r = average_bgr[2]
#print(str(int(average_b)) +", "+ str(int(average_g)) +", "+ str(int(average_r)))
```

Figure 2: Python program for extracting R,G,B values.

C. Classification

The classifier used for differentiating mature from immature coffee beans are the 23 machine learning algorithms of Matlab's Classification Learner App (CLA). The extracted RGB color features were inputted to the CLA using 5 folds , this means that 80 beans were used for training and the 20 beans were used for testing and validation. The accuracy and training time were taken into account to determine which is the best classifier of the mature and immature coffee beans.

3. RESULTS AND DISCUSSION

The extracted features of mature and immature coffee beans is shown in Table 1. It can be seen in Table 1 that the RGB values for mature and immature coffee beans are overlapping. It can also be observe that RGB values of mature coffee beans are lower than the RGB values of immature coffee beans.

Table 1: RGB Range of Values for Mature and Immature Coffee Beans

Coffee Bean Type	Red	Green	Blue
Mature Coffee Beans	74 to 143	89 to 163	89 to 159
Immature Coffee Beans	90 to 150	100 to 168	104 to 164

Table 2 shows the classification results for the 23 machine learning algorithms

Table 2: Classification Results

Classifier Type	Accuracy (%)	Training Time (Seconds)
Fine Tree	84	27.91
Medium Tree	84	0.32
Coarse Tree	81.5	0.21
Linear Discriminant	94	7.12
Quadratic Discriminant	93	0.97
Logistic Regression	93	26.30
Linear Support Vector Machine (SVM)	94	6.33
Quadratic SVM	94	0.62

Cubic SVM	93	11.4
Fine Gaussian SVM	93	0.35
Medium Gaussian SVM	92.5	0.21
Coarse Gaussian SVM	80.5	0.19
Fine KNN	84	3.26
Medium KNN	89	0.21
Coarse KNN	74.5	0.20
Cosine KNN	92	0.53
Cubic KNN	91.5	0.25
Weighted KNN	87.5	0.29
Boosted Trees	82.5	5.67
Bagged Trees	85	3.05
Subspace Discriminant	93	2.59
Subspace KNN	81.5	2.46
RUS Boosted Trees	84.5	5.25

Table 2 also shows that the Linear SVM and Quadratic SVM both achieved the highest accuracy of 94 %, however in terms of training time the fastest was achieved by quadratic SVM with 0.64 seconds, compared to 6.33 seconds of linear SVM. The CLA setting known as the Principal Component Analysis (PCA) was not used in the classification.

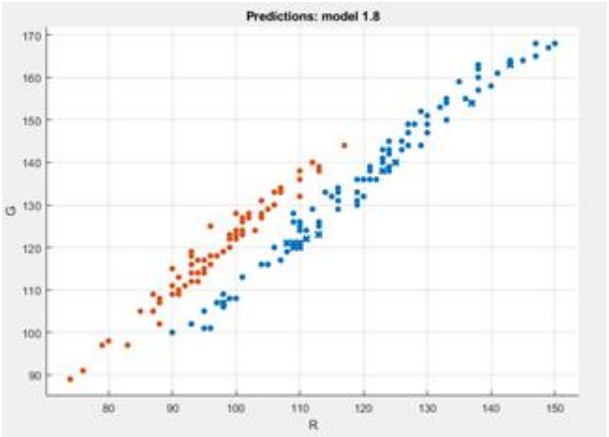

Figure 3: Scatter Plot of the Quadratic SVM Classifier

Figure 3 shows that the 10 features are overlapping for civet coffee and normal robusta coffee beans.

Figure 4 shows the Confusion Matrix of the Quadratic SVM classifier.

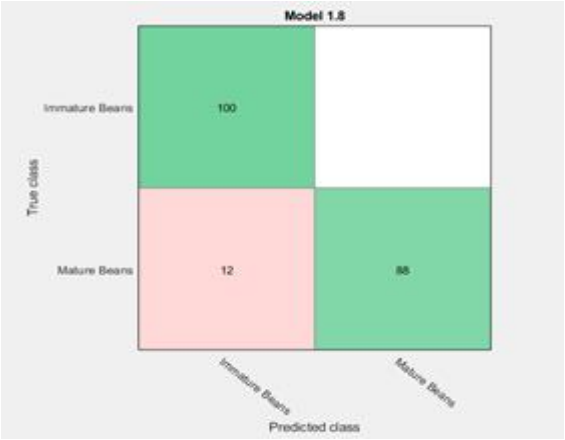

Figure 4: Confusion Matrix of the Quadratic SVM Classifier

It can be seen in Figure 4 , the confusion matrix that the Quadratic SVM Classifier was able to correctly identify immature coffee beans by 100 % and mature coffee beans by only 88%.

Figure 5 shows the Receiver Operating Characteristic (ROC) curve of the Quadratic SVM.

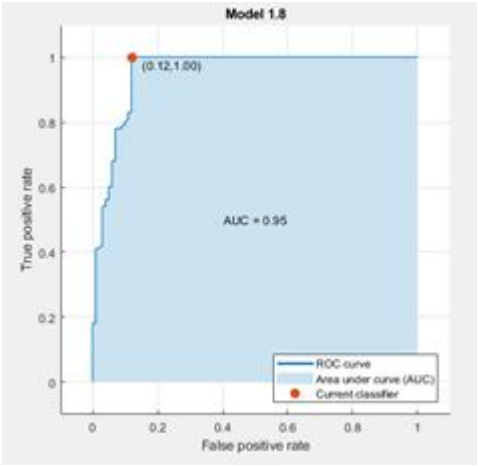

Figure 5 : The ROC Curve of Quadratic SVM Classifier

In Figure 5 the area under the curve (AUC) of the Quadratic SVM is equal to 0.95. The more the AUC value approaches 1, the higher the accuracy of the classifier. The AUC value of 0.95 of Quadratic SVM is the best AUC value compared to other classifiers.

Figure 6 show the parallel coordinates plot of the quadratic SVM .

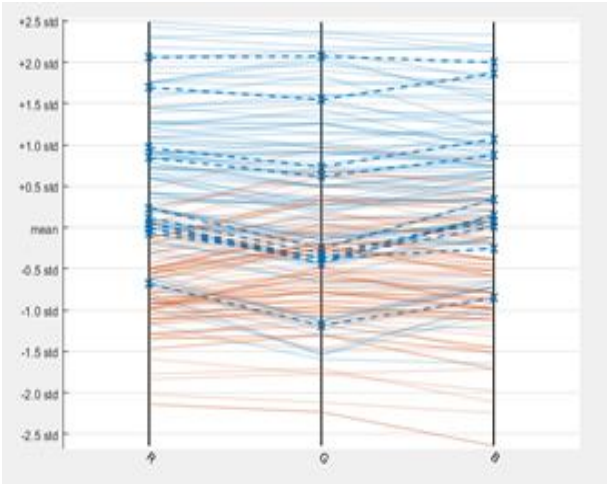

Figure 6: The Parallel Coordinates Plot of Quadratic SVM Classifier

The parallel coordinates plot shows the useful variables or features namely the RGB values of the mature and immature coffee beans that contributed to their discrimination . It can be seen in the plot that the RGB features of the mature and immature coffee beans overlapped by still the Quadratic SVM algorithm was able to discriminate the two bean group with 94% accuracy.

4. CONCLUSION

The paper is about answering the research question whether mature and immature coffee beans can be differentiated using RGB features extracted using image processing and classified using machine learning algorithms. It can be concluded that the RGB of mature beans differ with RGB of immature beans. This was achieved by using the Quadratic SVM algorithm with 94 % accuracy at a training speed of 0.62 seconds.

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APPENDIX

THE DATASET OF THE STUDY

Sample	R	G	B	Classes
1	88	108	109	Mature Beans
2	95	115	118	Mature Beans
3	97	118	121	Mature Beans
4	95	115	117	Mature Beans
5	103	124	127	Mature Beans
6	99	120	122	Mature Beans
7	110	132	134	Mature Beans
8	104	128	127	Mature Beans
9	88	102	107	Mature Beans
10	92	111	113	Mature Beans
11	95	114	116	Mature Beans
12	91	109	112	Mature Beans
13	90	111	112	Mature Beans
14	83	97	103	Mature Beans
15	76	91	95	Mature Beans
16	91	113	117	Mature Beans
17	93	118	120	Mature Beans
18	102	127	131	Mature Beans
19	107	133	132	Mature Beans
20	100	128	127	Mature Beans
21	107	134	133	Mature Beans
22	101	126	129	Mature Beans
23	96	125	123	Mature Beans
24	106	133	132	Mature Beans
25	100	124	126	Mature Beans

26	102	128	130	Mature Beans
27	90	115	114	Mature Beans
28	93	116	119	Mature Beans
29	93	119	117	Mature Beans
30	107	133	134	Mature Beans
31	101	124	126	Mature Beans
32	107	134	129	Mature Beans
33	106	130	129	Mature Beans
34	104	131	126	Mature Beans
35	106	130	130	Mature Beans
36	98	119	120	Mature Beans
37	104	127	128	Mature Beans
38	95	117	117	Mature Beans
39	101	127	123	Mature Beans
40	93	114	116	Mature Beans
41	99	123	121	Mature Beans
42	80	98	97	Mature Beans
43	93	119	114	Mature Beans
44	79	97	99	Mature Beans
45	110	136	135	Mature Beans
46	105	129	131	Mature Beans
47	96	116	121	Mature Beans
48	99	123	123	Mature Beans
49	117	144	141	Mature Beans
50	113	139	137	Mature Beans
51	112	140	136	Mature Beans
52	113	138	138	Mature Beans
53	100	122	121	Mature Beans
54	100	123	123	Mature Beans
55	110	138	134	Mature Beans
56	93	112	116	Mature Beans
57	99	122	121	Mature Beans
58	91	110	113	Mature Beans
59	90	109	110	Mature Beans
60	101	126	123	Mature Beans
61	100	124	120	Mature Beans
62	94	117	117	Mature Beans
63	88	107	107	Mature Beans
64	101	123	122	Mature Beans
65	94	112	114	Mature Beans
66	92	111	113	Mature Beans
67	94	114	114	Mature Beans
68	96	118	115	Mature Beans
69	91	110	112	Mature Beans
70	87	105	106	Mature Beans
71	94	114	114	Mature Beans
72	85	105	103	Mature Beans
73	74	89	89	Mature Beans
74	87	109	106	Mature Beans
75	101	126	123	Mature Beans
76	100	124	120	Mature Beans
77	94	117	117	Mature Beans
78	88	107	107	Mature Beans
79	101	123	122	Mature Beans
80	94	112	114	Mature Beans
81	92	111	113	Mature Beans
82	94	114	114	Mature Beans
83	96	118	115	Mature Beans
84	91	110	112	Mature Beans
85	87	105	106	Mature Beans
86	94	114	114	Mature Beans
87	85	105	103	Mature Beans
88	74	89	89	Mature Beans
89	113	123	134	Mature Beans
90	137	154	157	Mature Beans
91	109	121	131	Mature Beans
92	125	140	145	Mature Beans
93	110	121	129	Mature Beans
94	109	120	131	Mature Beans
95	111	122	130	Mature Beans
96	110	120	131	Mature Beans
97	108	121	125	Mature Beans
98	98	107	116	Mature Beans
99	143	163	159	Mature Beans
100	123	138	142	Mature Beans
1	113	123	134	Immature Beans
2	137	154	157	Immature Beans
3	109	121	131	Immature Beans
4	125	140	145	Immature Beans
5	110	121	129	Immature Beans
6	109	120	131	Immature Beans
7	111	122	130	Immature Beans
8	110	120	131	Immature Beans
9	108	121	125	Immature Beans
10	98	107	116	Immature Beans
11	143	163	159	Immature Beans
12	123	138	142	Immature Beans
13	136	155	153	Immature Beans

14	119	133	139	Immature Beans
15	130	147	146	Immature Beans
16	100	108	118	Immature Beans
17	123	140	140	Immature Beans
18	113	123	134	Immature Beans
19	111	124	126	Immature Beans
20	113	125	130	Immature Beans
21	140	158	154	Immature Beans
22	124	138	138	Immature Beans
23	116	129	132	Immature Beans
24	127	144	140	Immature Beans
25	121	136	134	Immature Beans
26	96	101	115	Immature Beans
27	120	132	138	Immature Beans
28	150	168	164	Immature Beans
29	119	130	138	Immature Beans
30	147	165	161	Immature Beans
31	124	139	139	Immature Beans
32	129	144	144	Immature Beans
33	113	126	132	Immature Beans
34	95	101	113	Immature Beans
35	98	106	116	Immature Beans
36	119	131	136	Immature Beans
37	145	164	156	Immature Beans
38	113	125	129	Immature Beans
39	122	136	136	Immature Beans
40	130	149	142	Immature Beans
41	149	167	161	Immature Beans
42	113	125	130	Immature Beans
43	107	117	127	Immature Beans
44	104	116	117	Immature Beans
45	95	105	111	Immature Beans
46	121	138	135	Immature Beans
47	133	150	148	Immature Beans
48	122	136	139	Immature Beans
49	105	116	120	Immature Beans
50	126	143	141	Immature Beans
51	106	120	127	Immature Beans
52	108	119	129	Immature Beans
53	128	149	150	Immature Beans
54	106	120	127	Immature Beans
55	126	145	148	Immature Beans
56	114	133	134	Immature Beans
57	98	109	118	Immature Beans
58	133	155	152	Immature Beans
59	138	160	155	Immature Beans
60	130	151	150	Immature Beans
61	124	142	146	Immature Beans
62	115	132	136	Immature Beans
63	110	125	130	Immature Beans
64	110	124	130	Immature Beans
65	99	108	119	Immature Beans
66	143	164	162	Immature Beans
67	132	153	148	Immature Beans
68	138	163	152	Immature Beans
69	123	141	142	Immature Beans
70	127	149	144	Immature Beans
71	109	126	126	Immature Beans
72	97	107	118	Immature Beans
73	123	143	142	Immature Beans
74	141	161	157	Immature Beans
75	124	143	140	Immature Beans
76	138	157	156	Immature Beans
77	135	159	147	Immature Beans
78	120	136	139	Immature Beans
79	101	113	119	Immature Beans
80	138	162	153	Immature Beans
81	115	132	134	Immature Beans
82	121	139	140	Immature Beans
83	124	143	143	Immature Beans
84	116	133	134	Immature Beans
85	99	108	118	Immature Beans
86	121	139	141	Immature Beans
87	130	149	144	Immature Beans
88	147	168	162	Immature Beans
89	133	154	146	Immature Beans
90	119	136	138	Immature Beans
91	124	145	140	Immature Beans
92	129	152	143	Immature Beans
93	112	129	131	Immature Beans
94	93	102	114	Immature Beans
95	116	134	133	Immature Beans
96	116	131	134	Immature Beans
97	109	128	125	Immature Beans
98	127	147	146	Immature Beans
99	90	100	104	Immature Beans
100	110	126	129	Immature Beans