Classification of arecanut using machine learning techniques

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ABSTRACT

In agricultural domain research, image processing and machine learning techniques play an important role. This paper provides a unique solution for classifying the good and defective arecanuts based on their color, texture, and density value. In the market different varieties of arecanut are available. Usually, qualitative sorting is done manually, and this can be replaced by applying machine vision techniques to grade the arecanut. Classification of arecanut based on quality is done using various machine learning techniques and it is observed that artificial neural networks give good results compared to other classifiers like logistic regression, *k*-nearest neighbor, naive Bayes classifiers, and support vector machine. A unique density feature is considered here for better classification. The result of classifiers without considering the density feature is compared with respect to the density feature and it is observed that artificial neural networks work better than the others. The proposed method works effectively for classifying arecanut with an accuracy of 98.8%.

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1. INTRODUCTION

The use of technology in agriculture was initially used for simple and precise calculations, which were found to be relatively difficult in manual calculations. In the next generation, research decision support systems will be developed to take tactical decisions on agricultural production and protection. Arecanut is a major cash crop in the undivided Dakshina Kannada district and Malnad region. Areca Catechu Linn is the scientific name of the arecanut and it is also called betelnut in India. In India, the cultivation and use of arecanut have their own unique practice [1]. In the food processing industry nowadays, there is a requirement for the production of quality products at a very fast rate, so developing an expert system helps to make decisions in less time. In manual grading, individual person perception makes differences in identifying whether a product is defective or healthy, but this machine vision framework will decrease such human errors and help to perform at a faster rate.

Arecanut is used for making supari, areca tea, and paint. It has its own value in several religious ceremonies. In the Indian's ancient medicine system book of i.e., *Dhanwantari Nighantu*, it mentioned the use of arecanut as one of the five natural aromatics (*panchasugandhikam*) along with pepper, clove, nutmeg, and camphor. In the Indian subcontinent, the chewing of betel leaf and arecanuts back to the pre-Vedic period of the Harappan Empire [2]. The beginning of the arecanut cannot be traced exactly, but in the Philippines or Malaysia, it probably originated. Usage of nuts for chewing initially started in Vietnam and Malaysia. Then it moved to other parts of the world and was recognized as a cash crop [3]. In the global scenario, India is top in arecanut production in the world. As the country develops, even the cultivation and processing techniques of the crop improvement. As we produce more arecanut, we have to give more importance to quality, because quality is one of the important metrics to evaluate the product while exporting.

Ripped arecanuts, which are shown in Figure 1, are used on a daily basis, but for long-term storage, fully ripe arecanuts are dried in the sun for 35 to 40 days before being dehusked and marketed as whole nuts. Inadequate drying of nuts results in fungal infection and which leads to a poor-quality product. Arecanuts reduce weight due to fungal infection [4] and even *koleroga* (fruit rot) disease affected nuts are in lighter weight and make dark brown radial stand internally [5].

Figure 1. Arecanut images

In the market, arecanut is available in two categories, i.e., with and without husk. In this proposed work, arecanut without husk is considered. Sometimes good quality arecanut will be mixed with diseased or spoiled arecanut but distinguishing between the two is a difficult task that requires experts. If a spoiled arecanut shows any changes in outer appearance, then it can be segregated easily, but in some cases, the arecanut may not show any much noticeable changes from the outside. To check the quality, we have to cut and see (check) some samples from the stored arecanut. If we replace this manual method with digital, we can save samples as well as effort.

Image processing plays an important role in the agriculture domain [6], [7]. However, image segmentation is influenced by a variety of elements such as image type, color, and noise level, [8]. Originally, the image will be in red, green, and blue (RGB) color space. However, it may be converted to other color spaces such as Lab; hue, saturation, value (HSV); and cyan, magenta, yellow (CMY) [9]. The outcome of segmentation differs depending on the color space used. As a result, selecting the right color space for a dataset is critical. Many segmentation techniques like thresholding, region growing, and clustering are presently available and widely used in image segmentation [10]. Thresholding is one simple form of segmentation method [11]. Many of the clustering algorithms [12] are used to get the region of interest from a given image. K-means is the most popular one because of its simple and fast nature [13].

Different image processing technologies have been used in many fields of agriculture, i.e. the studies on plant diseases, grading of agricultural products based on quality, and finding the nitrogen deficiency of the product, and this helps to reduce manual effort [14]–[16]. If we combine advanced image processing methods with machine learning techniques, it will be more beneficial to farmers. Many such techniques are used in the grading of agricultural product and a few are listed below.

A neural network is suitable for content-based image classification [17]. In the fruit grading system, an artificial neural network (ANN) is used and produced good results [18]. Tiger and Verma [19] presented an apple recognition system for differentiating normal and infected apples using ANN. Olaniyi *et al*. [20] developed an intelligent system for banana fruit grading using ANN and got 97% accuracy. With this fruit grading concept, we can extend our work to sort the arecanut. Ohali [21] has proposed a computer vision-based approach for grading dates. They employed RGB images of date fruits and retrieved exterior quality parameters such as texture, size, shape, and intensity, from these images. They sorted dates into three quality groups based on the collected characteristics and the usage of a back propagation neural network classifier. Testing was also done on pre-selected dates' samples, and the system's accuracy was validated. According to the results of the tests, the system can correctly arrange dates in 80% of the cases. Pourdarbani *et al*. [22]

conducted research comparing human and machine vision in classifying different sorts of dates. The dates were classified using the *k*-means classifier approach based on color components, and the results were compared to human vision findings.

Few works are done for arecanut grading based on categories. Suresha *et al.* [23], [24] proposed a technique to classify both raw and processed arecanuts, where they used *k*-nearest neighbor (*k*-NN) by considering texture features and got 74.33% accuracy. In the next paper, they classified arecanut using *k*-NN and decision trees. Six varieties of arecanuts are considered for this work, namely Api, Red Bette (RB), Black Bette (BB), Minne, Gotu, and Chaali. We find that the decision tree gives good results compared to *k*-NN. Bharadwaj *et al*. [25] proposed employing texture-based block-wise local binary to categorize husk-removed arecanut into distinct groups, i.e., Hasa, Bette, Gorabalu, and Idi. In this experiment, texture features are extracted in the form of local binary patterns, and then a support vector machine classifier is used for classification, where they got 94% accuracy for 8 blocks of the image.

The neural network can be applied in any field of engineering or science where there is a problem of classification [26]. Huang [27] used a back propagation neural network (BPNN) to categorize arecanut into three primary categories i.e., excellent, good, and bad by examining color and geometric aspects of the arecanut and obtained 90.9 percent accuracy. Siddesha *et al.* [28] suggested a method for distinguishing between color segmentation approaches for arecanut crop bunches. This work mainly focuses on color segmentation techniques like watershed segmentation, thresholding, *k*-means clustering, fuzzy c-means (FCM), fast fuzzy c-means clustering (FFCM), and maximum similarity-based region merging (MSRM). The assessment was then carried out using several arecanut picture datasets based on the segmentation findings. For classification, the nearest neighbor (NN) classifier was utilized. The test was done using a dataset of 700 photos from seven distinct classes to illustrate the suggested model's performance and achieved a classification rate of 91.43%. Siddesha *et al.* [29] conducted an experiment to grade the arecanut. Only texture features are considered from arecanut and the *k*-NN classifier was used for classification.

According to the findings of the literature review, it was observed that little work has been done on the classification of arecanuts based on quality using computer vision. Common features used for arecanut grading are color, texture, and shape. As ours is husk removed arecanut grading with respect to quality, so the shape feature is not very prominent, so the existing color and texture are used. With these two features, the usage of the density feature is a new approach that has been used for arecanut classification in this work.

2. RESEARCH METHOD

In this proposed work, a husk-removed arecanut dataset is considered. All images are taken by considering the same distance and device with a unique homogeneous white color background. The captured image is given for further pre-processing to get a better final result. A median filter is used to remove the noise and then the image is converted to HSV color space. Then the hue component is considered further, and a clustering algorithm is applied to the image to separate the arecanut from the background image. From segmented images, texture, color, and density features are extracted, and the model is trained using ANN classifiers. Finally, new samples are tested or classified into either healthy or defective classes. Finally, the constructed model is tested with new samples to crosscheck the classifier and how effectively it classifies (grades) the arecanut. The experimental workflow of the arecanut grading system is given below. Figure 2 shows the clear working steps of the arecanut grading system. The classification system has two components: training and testing. In the first component, an arecanut classification training model is built by using arecanut images, and then the same model is used for classifying the newly given arecanut images to test it.

2.1. Segmentation

Segmentation is applied to an arecanut image to get the region of interest from the image. Our region of interest is arecanut, which we need to separate from the background of the image. Different segmentation algorithms are available and here simple *k*-means clustering is used to separate the arecanut from the background image.

The algorithm for *k*-means clustering is given below: i) the data is clustered into 'k' groups where *k* has a predefined value; ii) as cluster centers, *k* points are selected at random; iii) according to Euclidean distance, data points are assigned to their closest cluster; iv) in each cluster, the centroid of all objects is calculated; and v) steps from ii to iv are repeated until the same points are assigned to each cluster in successive rounds.

From the *k*-means result, each pixel in the image is grouped based on similarity and gives a cluster that consists of similar pixels. Color based segmentation is used to segment the original image based on color. This action will result in *k* clusters of the original image that is partitioned by color. When segmentation is complete, one of the clusters containing the arecanut part is considered for further processing.

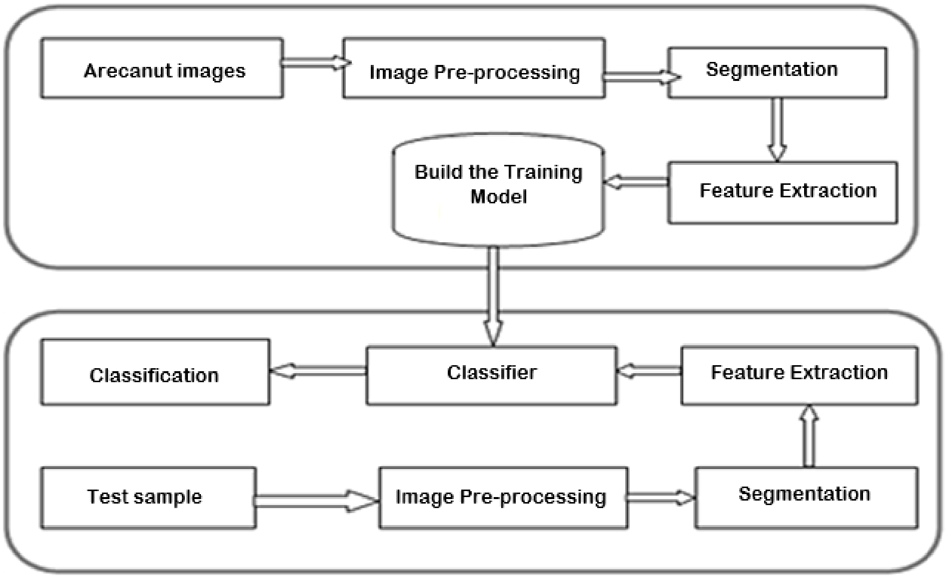


Figure 2. Proposed arecanut classification system

2.2. Feature extraction

The segmented image separates arecanut from the background image and features are extracted from segmented images. Three main types of features are extracted, i.e., texture, color, and density.

- Texture: Grey level co-occurrence matrix (GLCM) is used for extracting the texture features. From the arecanut image texture features like contrast, energy, homogeneity, variance, and entropy are extracted.
- Color: Differentiating the object due to color variation is one of the easiest methods. Color features like mean and standard deviation are used to extract the color of an object.
- Density: In arecanut classification, density features contribute more weightage in grading spoiled and good arecanuts, but every so often, arecanut will spoil when we store it for a long time with a lack of safety measures. Identifying this is very difficult because it may or may not make any much noticeable changes from the outside, but it will reduce the weight [4], [5]. So, a good arecanut will be denser than a spoiled (defected) arecanut due to moisture variation. While considering the weight of the arecanut, we have considered the area, because different sizes of arecanut can have the same weight. For example, a healthy and spoiled arecanut may have the same weight but different sizes. So, for classification, only consider the color and texture features that may not be prominent, but combining the weight factor of the arecanut with color and texture features gives more accurate information.

Density is estimated as mass/volume from the area obtained in the image and the weight and height are obtained separately.

$$Volume = Area * Height \quad (1)$$

$$Mass = \frac{Weight}{g} \quad (2)$$

$$Density = \frac{Mass}{Volume} \quad (3)$$

To calculate the area, the color image is converted to binary. Then the binary image area is calculated by counting the number of pixels. Area is converted to centimeters by calculating the number of pixels per centimeter. Weight and height have been given as input values. Weight and height should be converted to meters. Volume is calculated by (1) [30]. Mass is calculated using (2). Weight must first be converted to kilograms because g is 9.8 m/s^2, where g is the acceleration due to gravity. Finally, from the above values, new feature is derived i.e., density is calculated using (3).

2.3. Classification

Classification is a technique for determining the class of a new observation using training data with a known class label. This contains two phases i.e., training and testing. Classification can be carried out using a variety of classifiers like logistic regression, *k*-NN, naive Bayes classifiers, support vector machine (SVM), and ANN.

2.3.1. Logistic regression

Logistic regression is used to allocate observations to a distinct set of classes. In regression analysis, logistic regression estimates the parameters of a logistic model. It is a predictive analysis algorithm based on the concept of probability.

2.3.2. *k*-nearest neighbor

k-NN is an easy-to-implement and simple algorithm. Based on similarity new data is classified. When new data appears, it can be categorized with more matching categories by using the *k*-NN algorithm. It is also called a lazy learner because it does not learn from the training set immediately; instead, it stores the dataset and at the time of classification, it performs an action on the dataset.

2.3.3. Naive Bayes classifiers

Naive Bayes is a statistical classifier which works based on the Bayesian theorem and which uses probabilistic analysis concepts for classification. This classifier gives good results in less computation time. Naive Bayesian classifiers are probabilistic classifiers that are based on the Bayes theorem. Bayes' theorem is given in (4),

$$P(y|X) = \frac{P(X|y)\,P(y)}{P(X)} \tag{4}$$

where *Y* indicates a class variable, *X* indicates the dependent feature vector of size n i.e. $X=(x_1, x_2, ..., x_n)$

2.3.4. Support vector machine

SVM constructs a hyperplane, and this is a separating line between two data classes in SVM. SVM has good prediction speed and memory utilization. When it comes to a small sample, nonlinear, and high-dimensional data, SVM has a lot of benefits. SVM works well for clear margin and high-dimensional space data. SVM is suitable for small datasets. For given training data $\{xi, yi\}$, where xi indicates data for training and *yi* indicates category, they are either 1 or −1, each signifying the class to which the data point xi belongs.

2.3.5. Artificial neural network

An ANN is a mathematical model used for pattern recognition. The main concepts replicated here are neurons, dendrites, and axons, which are commonly referred to as nodes, weights, and hidden layers along with input and output layers. There are various types of ANN such as feed-forward, convolutional, and modular. The results indicate that the Marquardt algorithm is a standard optimization algorithm to train the feed-forward network and is very efficient when training networks that have up to a few hundred weights [31].

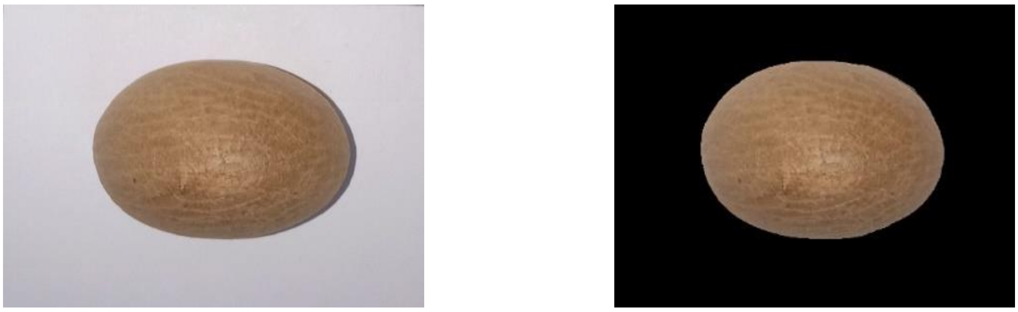
Feedforward with back propagation neural network is one of the powerful techniques where errors obtained at the output are corrected by tracing back the network and correcting the relevant weights associated with the nodes. This method is widely used because it works well even with noisy data and can be used to solve complex problems. The Levenberg-Marquardt optimization function is used to update the weight and bias. This algorithm is intended to minimize sum-of-square error functions [32]. Minimizing the modified error with respect to (5).

$$w(j+1) = w(j) - (Z^T Z + \mu I)^{-1} \; Z^T e(j) \tag{5}$$

Very large values of µ (mu) amount to the standard gradient descent, while very small values µ amount to the Newton method. The network is designed with one hidden layer and seven hidden neurons. The adaptive value Momentum update (mu) is increased until the change above results in a reduced performance value. The initial mu value considered is 0.001.

3. RESULTS AND DISCUSSION

Segmentation separates regions of interest from the background. In this work, our region of interest is arecanut and a clustering algorithm is used to separate the arecanut from the remaining background. This is shown in Figure 3. Figure 3(a) shows the preprocessed arecanut image and Figure 3(b) shows the extracted arecanut after segmentation.



(a) (b)

Figure 3. Arecanut image (a) before and (b) after segmentation

Images of husk removed arecanuts are considered for this experiment. A database contains two classes of data i.e., 'good' and 'defected'. Features like texture and color are considered. Logistic regression, *k*-NN, naive Bayes, SVM, and ANN classifiers are applied to the data. The results of different classifiers are compared and are shown in Table 1.

Table 1 observed that ANN works better on our arecanut data compared to other algorithms. So, ANN is considered for further experiments. Next worked on arecanut data by considering the density feature and explained below. Table 2 gives the result of different classifiers by considering density features. There observed that ANN gives a higher accuracy of 98.8% compared to other classifiers.

Table 1. Accuracy comparison of classifiers before using density features

Classifier	Accuracy (%)
Logistic Regression	90.2
k-NN	91.6
Naive Bayes	86.6
SVM	90.2
ANN	92.8

Table 2. Accuracy comparison of classifiers after using density features

Classifier	Accuracy (%)
Logistic Regression	93.9
k-NN	96.3
Naive Bayes	91.5
SVM	95.1
ANN	98.8

Figure 4 depicts a performance comparison of various classifiers such as logistic regression, *k*-NN, naive Bayes classifiers, SVM, and ANN s when considering and not considering density features. From the above result, it is observed that an ANN with a density feature works better for classifying the healthy arecanut from the spoiled one. So, we can observe from the above comparison that density features play an important role in arecanut classification.

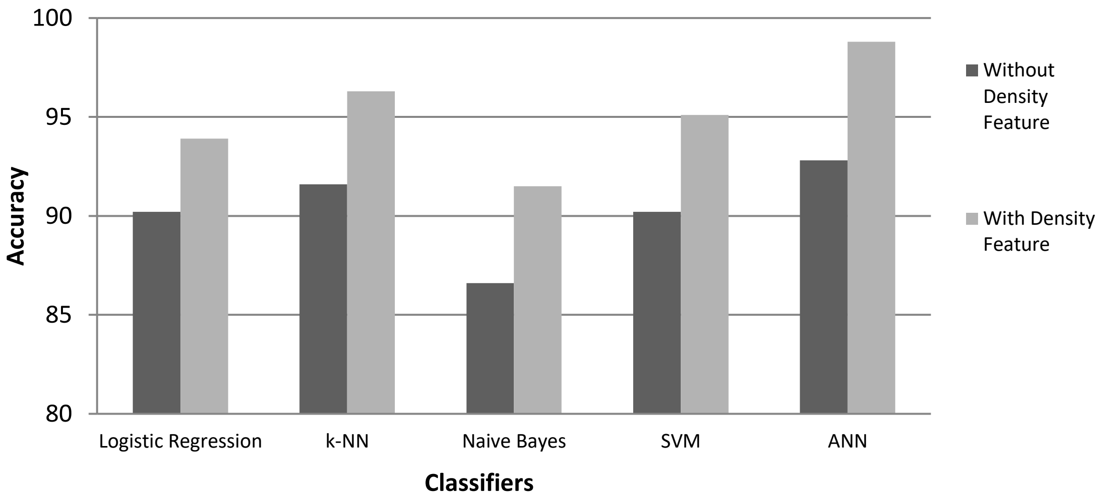


Figure 4. Performance comparison of different classifiers

4. CONCLUSION

In this paper, an arecanut classification system is developed for grading the good and spoiled arecanuts through color and texture features and classified using classifiers like logistic regression, k-NN, naive Bayes, SVM, and ANN classifiers. Results are compared and it is found that ANN works better than other classifiers. A further arecanut classification system is developed using back propagation neural networks by considering the color, texture, and density features of arecanut. These unique density features are derived from the area, height, and weight parameters of the samples. This developed machine vision system with a density feature is compared with a classifier without considering the density feature. After considering the newly derived density feature, arecanut grading system gives 98.8% overall accuracy. An experimental result reveals that this developed machine vision system with density features gives a good success rate. This grading system helps to reduce human effort and the time required for manual sorting. In the future, we can extend this work by applying more data with extra suitable features and deep learning can be applied.

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