Arabica Coffee Bean Quality Identification Using Support Vector Machine-Based Digital Image Processing

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Abstract: Existing institutions already began performing actions regarding the originality certification of coffee bean varieties and their quality. The purpose of this research paper was to investigate how technology can assist in performing evaluations through image analysis. Specifically, the study focused on developing a system to classify the quality and size of Arabica coffee beans. The system utilized image processing to analyze morphological features of coffee bean images, including area and perimeter. By combining these features and using a support vector machine (SVM) classifier, the system achieved an accuracy rate of 95% in identifying coffee bean quality and size. These findings suggest that technology-based tools can effectively assist with object evaluation, particularly in the context of coffee bean classification.

Keywords: Arabica Coffee Bean, Convolutional Neural Networks, Image Processing, Originality Certification, Support Vector Machine,

1. Introduction

Many tropical and subtropical countries rely on one of the main agricultural activities to generate foreign cash. Based on the volume of commerce, coffee is the second most significant product on the market, and based on value, it is projected to be the first. The quality of the coffee bean determines its color, texture, size [9] and price, which is directly related to how it will taste when brewed. Computer vision is the field of study that creates the theoretical and algorithmic basis [2].The useful information may now be automatically collected and analyzed by looking at an image and using computer- generated calculations [6].Due to benefits like economy, accuracy, and objectivity in terms of their ability to provide numerical data with features like size, shape, color, and texture, computer vision is increasingly being used to carry out tasks for quality inspection, sorting, and automatic processes in the agricultural industry [3].

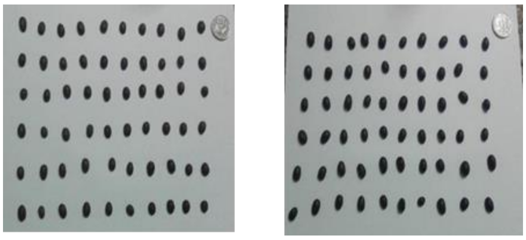
In the food sector, morphological characteristics such area, perimeter, length, minor axis, major axis, eccentricity, and density are frequently used in automatic sorting, quality assessment, and product quality detection [9]. Though not all agricultural products have exclusive scientific use, the aforementioned characteristics do. The typical variety of these goods makes the work of identification and classification exceedingly difficult and computationally intensive [4]. This is because a significant number of classification variables must be present.

Artificial neural networks have a clear advantage in the categorization process when used as automation decision algorithms in computer vision. The development of computer vision in the classification of agriculture products by using artificial neural networks could be found in several kinds of research [7][8].

2. Methods

2.1 Coffee Beans

Detailed The brightly colored red or purple fruits of coffee plants contain the seeds known as coffee beans. When the fruits are ready, either humans or machines meticulously select them. The coffee bean is seen once the cherry, the fruit's outer shell, has been removed. The remaining layers are then removed from these beans using a dry or wet processing technique to make sure they are prepared for roasting. The essential process of roasting the coffee beans brings out their distinctive flavors and fragrances. After being roasted, the beans can be crushed and used to make coffee, a delectable brew. The type and origin of the coffee beans have a vital influence in generating the distinctive experience of your favorite cup of joe, whether you prefer a smooth and mild flavor or a robust and rich flavor The main text for your paragraphs should be 10pt font. All body paragraphs (except the beginning of a section/sub-section) should have the first line indented about 3.6 mm (0.14"). All of the samples of Arabica coffee beans that are used for this research were obtained from NCRDEC. A camera is used to acquire and capture the images of coffee beans with different sizes. They were arranged accordingly so that the processing and analyzing of image will be more applicable and the coffee bean number will be easy to identify. The camera is mounted at a fixed position and a certain distance between the lens and the samples with uniform background. The background used was color white. The uniform intensity of light is provided on the sample table. Inside the field of views, the beans were arranged in 10x6 orientation and position half of inch away to each other. Acquired image stores in jpeg format and parameters were extracted from the image for further analysis.



(A) (B)

Figure 1. Original Image of Arabica Coffee Beans

2.2 Image Acquisition

The process of digitizing visual information from the physical world for further processing and analysis is known as image acquisition. It is an essential stage in several disciplines, such as remote sensing, computer vision, medical imaging, and scientific investigation. For subsequent image-based applications to produce accurate and dependable results, high-quality image capturing is a must. Depending on the particular needs of the application, different devices are used for image acquisition. Digital cameras are frequently used for general imaging because they include high-resolution sensors and a variety of settings to take pictures in varied lighting situations. For specific objectives like temperature readings or object analysis in various spectral bands, specialized imaging systems like thermal cameras or hyper spectral cameras are used. Several significant factors must be considered during the image capture process. To produce images that are clear and informative, it is essential to consider variables including resolution, color fidelity, dynamic range, and noise levels. Accurate and reliable image acquisition is made possible by the proper calibration and synchronization of hardware elements including lenses, sensors, and light sources. Aperture settings, shutter speed, and exposure duration must also be modified according to the particular scene and intended result. As technology develops, image collecting methods continue to change. For example, computational imaging methods have arisen to improve the capabilities of conventional picture capture systems, such as multi-exposure fusion, focus stacking, and light field imaging. Through the use of computer methods and post-processing, these techniques allow for the capture of more scene information and image quality improvement.

A crucial step in bridging the actual world with digital representation is image collection. It lays the groundwork for later analysis, interpretation, and manipulation of visual data, making it a crucial component of many domains where visual data is necessary for understanding, decision-making, and research. The fast evolution of high-performance cameras in recent years has made them promising tools for observing transient and fast events in large-scale scientific experiments [5][20]. The captured images of coffee beans samples were taken by placing each sample on a white background, preferably just a short bond paper can be used. The position of camera was held to the plane of the sample about 14 cm away. The coffee beans samples were arranged and well separated on purpose to avoid samples touching each other, making segmentation easier and has a better accuracy especially in morphological features. In this work, 60 samples were used in the process and stored in JPEG (Joint Photographic Expert Group) format size 4160x2336.

2.3 Block Diagram

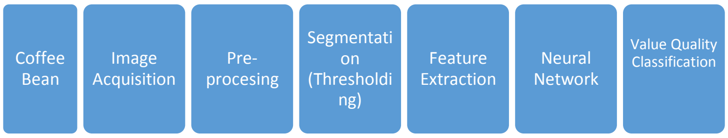


Figure 2. Block Diagram of the System Process

2.4 Image Pre-processing

To eliminate or diminish any artifacts, noise, or inconsistencies that might be present in the acquired images is the main objective of image pre-processing. Image denoising, image filtering, and picture enhancement are typical pre-processing methods.

Denoising techniques are used to minimize erratic changes or disruptions that could lower the image's quality. While retaining crucial visual features, undesirable high-frequency noise is removed using filtering techniques like Gaussian filters or median filters. To enhance certain characteristics or regions of interest as well as the general visibility of the image, image enhancement techniques including contrast adjustment and histogram equalization are used. Picture standardization and normalizing is a crucial part of picture pre-processing. To maintain consistency and comparability between various images or datasets, this entails modifying the image's scale, orientation, or color attributes. In order to align photographs using well-known reference points, scale pixel values to a given range, or account for fluctuations in lighting conditions are all examples of normalization procedures. When pre-processing an image, geometric modifications like cropping, rotation, and resizing may be used to customize it for a particular purpose or analytic method. These adjustments can be used to straighten out perspective flaws, focus on particular areas of interest, or align photos. In order to maximize the quality and usefulness of images for subsequent analytic tasks like image segmentation, object recognition, or image classification, image pre-processing is essential. Pre- processing techniques help to provide more accurate and dependable results by lowering noise, enhancing features, and standardizing image attributes, enabling the extraction of significant data and insights from digital images.

By the use of mobile camera or high-definition camera, the photos of coffee bean are captured, but it cannot used directly because it has a noise due to dust and light effect [19]. The researcher did not use flash of camera to obtain the proper light of the image. The capturing of image must be the same in distance and angle. Here, 60 samples of Arabica Coffee Beans (Light. dark and very dark) obtained from NCRDEC. To reduce the noise and blurredness of the image, the primary step is the image pre- processing [16]. The image then converted to black and white, grayscale and filled. The image cropping, resizing, thresholding and morphological operations were also done in this part.

2.5 Image Segmentation

The fundamental task of image segmentation in computer vision has received a great deal of attention due to the variety of disciplines in which it is used. In order to provide a more in-depth examination and comprehension of the image content, image segmentation aims to divide an image into relevant and homogeneous parts. Many strategies, from conventional ones to cutting-edge deep learning- based methodologies, have been developed over time to address this problem. Traditional techniques that rely on heuristics and basic picture attributes are edge detection, region-based segmentation, and thresholding. Convolutional neural networks (CNNs) have, however, completely changed the area of picture segmentation since the introduction of deep learning. By utilizing their capacity to learn high- level features and capture contextual data, CNN- based architectures like U-Net and Mask R-CNN have achieved exceptional performance. These models have been widely used in a variety of industries, such as autonomous vehicles, semantic scene interpretation, and medical imaging. Despite the tremendous development, there are still a number of difficulties in picture segmentation, including handling complex images, coping with unclear borders, and lowering computational complexity.

Through the investigation of novel network topologies, the incorporation of attention mechanisms, and the integration of multimodal data, current research attempts to address these issues. Additionally, there is ongoing research into metrics that can measure segmentation algorithm evaluation accuracy and spatial coherence. Overall, picture segmentation research is still active and showing signs of progress, providing new opportunities for enhanced visual analysis, object detection, and scene comprehension. Image segmentation plays an important role in a pre- processing phase of images having as objective a partition of the image into components or regions of interest for a more detailed analysis of one or more of these regions [13]. Threshold segmentation and clustering segmentation is based on the histogram dividing two modes, among them, the threshold segmentation refers to the use of one or several threshold gray histogram of the image can be divided into several categories [1], this kind of image segmentation technology finds that the grey value belong to the same object in the pixels in the same class, this is a direct use of gray level characteristics and operating way of image segmentation, the practical. From the generalized analysis, image segmentation is according to certain features or characteristics of the image collection, such as: gray, color, and liberal arts, etc., according to the similarity criterion, the image pixel grouping and clustering, plan to divide into several areas, these areas have some consistency, and do not overlap [18]. Image segmentation results should be uniformity and connectivity conditions at the same time, the segmentation of the image should have the integrity of the local. Segmentation is the process wherein the input image separates from its background area. In this process, the researchers used 227 thresholding to derive the result images.

Picture extraction, sometimes referred to as image extraction, is a critical step in computer vision and image analysis that entails removing pertinent visual information from complicated images or documents. In order to facilitate further analysis and interpretation, picture extraction aims to isolate and extract specific objects, areas, or visual features of interest from an image. Applications including document comprehension, object recognition, and visual information retrieval can all benefit from this method. There are two basic categories of image extraction techniques: manual extraction and automated extraction. Users manually designate or label the regions to be extracted using graphical tools or interfaces in manual extraction, which involves human intervention. Although time- and labor- consuming, this method offers fine-grained control. Contrarily, automated extraction approaches use computer algorithms and procedures to automatically recognize, and extract objects or regions based on visual signals like color, texture, shape, or semantic information. These procedures frequently combine machine learning techniques like clustering, classification, or deep learning with image processing methods including edge detection, picture segmentation, and feature extraction. Due to the availability of massive, annotated datasets, increased computing power, and the introduction of deep learning models, automated picture extraction has seen tremendous breakthroughs. In order to automatically extract visual information from photos with high accuracy and efficiency, convolutional neural networks (CNNs) and recurrent neural networks (RNNs) have demonstrated promising results. The handling of intricate backdrops, occlusions, or alterations in lighting conditions are still difficulties in picture extraction. Future research initiatives should focus on context-aware extraction algorithms, multimodal techniques that incorporate visual and textual information, and incorporating user feedback into interactive extraction systems. Picture extraction is still a topic of ongoing research with great.

2.6 Feature Extraction

Picture extraction, sometimes referred to as image extraction, is a critical step in computer vision and image analysis that entails removing pertinent visual information from complicated images or documents. In order to facilitate further analysis and interpretation, picture extraction aims to isolate and extract specific objects, areas, or visual features of interest from an image. In this image processing approach, the researchers used MATLAB (version 2015) to develop the computer routine algorithm to pre- process and extract the features of coffee beans sample images. After the pre-process procedure of the coffee bean images, features such as morphological characters were extracted for the value quality classification [12]. The said features from the extracted binary images produced by histogram thresholding of the gray scale images of the sampled coffee beans images.

2.7 Morphological Features

Morphological features are essential for image analysis and pattern identification because they reveal important details about the form, organization, and spatial properties of objects in an image. These features, which are derived from mathematical morphology, capture the geometrical characteristics and connections between areas and contours, allowing for a thorough depiction of object morphology. Numerous descriptive terms are included in morphological features, such as area, perimeter, eccentricity, convexity, solidity, and compactness. While perimeter counts the distance around an object's boundaries, area describes an object's size. Eccentricity quantifies an object's length or roundness and sheds light on its aspect ratio.

Convexity is a measurement of how convex an object is, indicating how concave it is. Solidity measures an object's compactness by comparing its area to its convex hull area. In numerous applications, including object recognition, texture analysis, and medical imaging, these morphological traits act as potent discriminative properties. Furthermore, to improve the analysis's resilience and discriminative strength, morphological features are frequently integrated with additional feature extraction methods like texture descriptors or color histograms. Even though morphological features have proven to be effective in a variety of fields, there are still difficulties with processing complicated object shapes, dealing with noise and variability in images, and choosing the right feature sets for certain tasks. Through the creation of sophisticated morphological feature extraction techniques, integration with deep learning models, and investigation of multi-scale and multi- resolution representations, ongoing research intends to overcome these issues. All things considered, morphological features offer a wealth of data for image analysis, allowing for improved comprehension, characterization, and discrimination of objects and patterns in a variety of visual data.

The most common measurements that are made on objects were those that describe shape [23]. Shape features are physical dimensional measures that characterize the appearance of an object [22]. Area, perimeter, major and minor axes lengths, and aspect ratio are some of the most commonly measured morphological features [14]. Morphological features are widely used in automated grading sorting and detection of objects in industry. Here is provided a description of the morphological features extracted from each coffee bean image.

- **Area (A)** - Area A of the kernel is measured as the number of pixels in the polygon.
- **Perimeter (P)** - Perimeter P is the mathematical sum of the Euclidean distances between all the successive pairs of pixels around the circumference of the kernel.
- **Major axis length (MA)** - The length of the major axis is the longest line that can be drawn through the object.
- **Minor axis length (MI)** – The length of the major axis is the longest line that can be drawn through the object perpendicular to the major axis.
- **Aspect Ratio (AR) (Elongation)** - The elongation ratio of the length of the minor axis to the length of the major axis. This is given as: AR = MA/MI
- **Circularity (Cr)** -This morphological attribute of the coffee beans is given by: Cr = (4 πA)/P2
- **Roundness (R) –** This attribute is described as: R = 4A/ πMA2
- **Feret Diameter (FD)** - This is the diameter of a circle having the same area as the object and is computed as: FD= [(4A)/ π]1/2

2.8 SVM Classifier

The supervised learning algorithm with a strong theoretical underpinning is the Support Vector Machine (SVM) classifier. The SVM classifier is thoroughly analyzed and evaluated in this study, with an emphasis on the algorithm's basic concepts, practical applications, and design. We go over the fundamental ideas of SVM, such as the margin maximization rule and the use of kernel functions to nonlinear classification. Additionally, we investigate many SVM variations, highlighting the benefits and drawbacks of each, including the linear SVM, polynomial SVM, and radial basis function (RBF) SVM. The paper examines the key procedures, such as feature selection, data preprocessing, and parameter optimization, involved in training an SVM classifier. Additionally, we go over the assessment measures frequently used to rate the effectiveness of SVM classifiers, covering factors like model choice and generalization. We demonstrate the efficacy and adaptability of the SVM classifier by a detailed study of real-world applications in a variety of fields, including image recognition, text classification, and bioinformatics. In order to provide insight into current developments in this subject, we conclude by analyzing recent developments, research problems, and probable future paths in SVM research.

The Support Vector Machine (SVM) algorithm is the supervised machine learning algorithm [15]. The SVM algorithm is used for different classification problems in various applications with great success. SVM classifier uses the special kernel function to construct a hyper plane separating the classes of data. The SVM classifier is used for training, testing, and classification [11]. The satisfactory quality of training and testing allows using the SVM classifier to classify the new object. Choosing optimal parameters for the SVM classifier is a significant problem. It is necessary to find the kernel function type, the values of the kernel function parameters and the value of the regularization parameter. It is impossible to provide implementing of high-accuracy data classification with the use of the SVM classifier without adequate solution to this problem [24].

3. Results

In this study, a pre-processing module, an image segmentation procedure, and feature extraction approaches are used to create the suggested system for coffee bean analysis. The coffee bean images are subjected to image processing operations using the MATLAB software. The acquired results offer insightful information regarding the evaluation of coffee bean quality using attributes that were extracted. Prior to further analysis, the pre-processing module is essential in improving the quality of the input photos. To achieve successful segmentation and feature extraction, a number of pre-processing techniques, including noise removal, contrast enhancement, and picture normalization are used. The coffee beans are separated from the image's background and other items using the image segmentation procedure. The coffee beans are precisely delimited by using suitable segmentation techniques, such as thresholding or region-based methods, enabling exact feature extraction.

Using the MATLAB software, various crucial parameters of the coffee beans are determined for feature extraction. These characteristics include its diameter, area, perimeter, minor and main axes, aspect ratio, circularity, and roundness. The minor and major axes explain the geometry of the coffee bean, while the area and perimeter give information about its size. To evaluate the bean's elongation or compactness, the aspect ratio is determined. Circular characteristics, such as circularity and roundness, reveal how closely something resembles a perfect circle. The largest distance between any two locations on the perimeter of the coffee bean is represented by the ferret diameter. It is possible to assess the quality of the coffee beans by examining these extracted properties. For instance, a higher-quality coffee bean can be indicated by a bigger size and perimeter. A bean may be considered more appealing if it has a circular shape and a lower aspect ratio. In addition, assessing the roundness and ferret diameter can reveal information about the general consistency of bean shape.

The outcomes of the examination of the coffee bean photos show how well the suggested system works to gauge the caliber of coffee beans. The quantitative measures provided by the extracted features are useful for grading and classifying coffee beans according to their quality characteristics. These discoveries provide the coffee industry with new opportunities for automation and efficiency enhancement, enabling better quality control and decision-making procedures. Overall, the execution of the suggested system demonstrates the potential of feature extraction and image processing methods for evaluating coffee quality. The conclusions drawn from the examination of coffee bean photographs offer insightful information and open the door to more study and advancement in this area.

3.1 Simulation Results of Food Image Preprocessing

The figure 3 Input coffee beans Image gives the input image, which is given as the Input to the pre- processing module by using the lab commands space conversion the input image is enhanced for making it fit for feature extraction figure 4 Image is the output of the extracted image in grayscale space conversion.

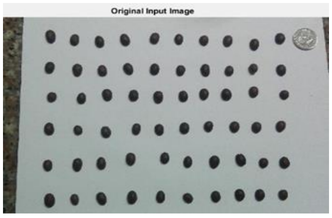


Figure 3. Sample original input image

3.2 Simulation Result of Image Segmentation

The input image is shown in the Figure 3 Input Coffee Bean Image is segmented using MATLAB. The output converted image is shown in figure 4 wherein the original image is in black and white and the filled image in black and white is present.

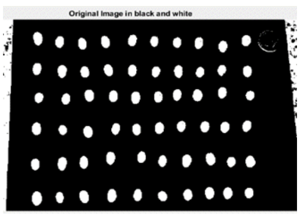


Figure 4.a

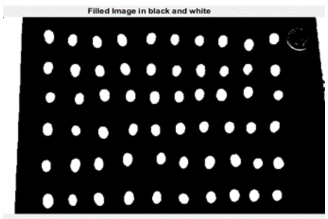


Figure 4.b

Figure 4.a Original Image in Black and White. Figure 4.a shows the original image of the coffee bean samples, turned into black and white using image processing. Figure 4.b Filled Image in Black and White. Figure 4.b has its edges smoothened so that the unnecessary black strokes on Figure 4.a is gone and won't interrupt on the main process.

3.3. Simulation Result of Morphological Features Using SVM Classifier

The scatter plot distinguished the coffee bean samples into three categories: bad quality(red), good quality(green), and best quality(blue).

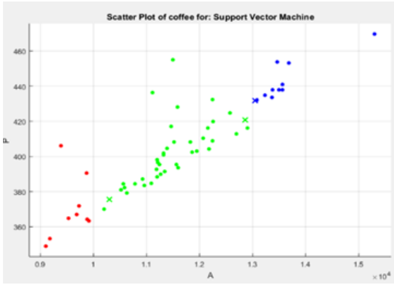


Figure 5. Output Scatter Plot Using SVM Classifier

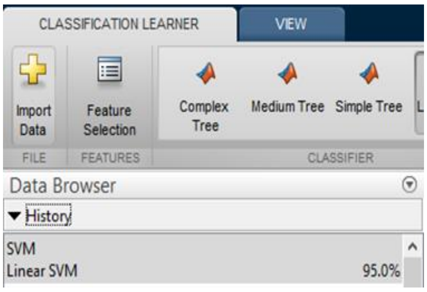
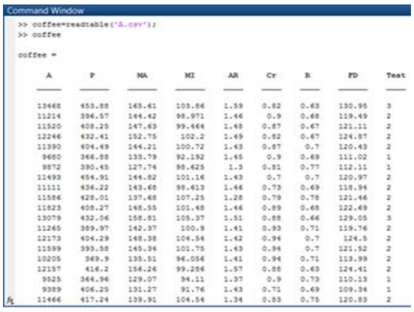


Figure 6. Output Percentage Accuracy



Command Window

```
>> coffee=readtable('A.csv');
>> coffee

coffee =
```

A	P	MA	MI	AR	Cr	R	FD	Test
13468	453.88	165.61	103.86	1.59	0.82	0.63	130.95	3
11214	396.57	144.42	98.971	1.46	0.9	0.68	119.49	2
11520	408.25	147.63	99.464	1.48	0.87	0.67	121.11	2
12246	432.41	152.75	102.2	1.49	0.82	0.67	124.87	2
11390	404.49	144.21	100.72	1.43	0.87	0.7	120.43	2
9680	366.88	133.79	92.192	1.45	0.9	0.69	111.02	1
9872	390.45	127.74	98.625	1.3	0.81	0.77	112.11	1
11493	454.91	144.82	101.16	1.43	0.7	0.7	120.97	2
11111	436.22	143.68	98.613	1.46	0.73	0.69	118.94	2
11586	428.01	137.68	107.25	1.28	0.79	0.78	121.46	2
11823	408.27	148.55	101.48	1.46	0.89	0.68	122.69	2
13079	432.06	158.81	105.37	1.51	0.88	0.66	129.05	3
11265	389.97	142.37	100.9	1.41	0.93	0.71	119.76	2
12173	404.29	148.38	104.54	1.42	0.94	0.7	124.5	2
11599	393.58	145.34	101.75	1.43	0.94	0.7	121.52	2
10205	369.9	135.51	96.056	1.41	0.94	0.71	113.99	2
12157	416.2	156.26	99.286	1.57	0.88	0.63	124.41	2
9525	364.96	129.07	94.11	1.37	0.9	0.73	110.13	1
9389	406.25	131.27	91.76	1.43	0.71	0.69	109.34	1
11466	417.24	139.91	104.54	1.34	0.83	0.75	120.83	2

Figure 7. Arabica Coffee Bean Database

The study successfully extracted eight variable parameters from an image of Arabica coffee beans and analyzed them using a SVM classifier method. By using image processing, the sample was classified into two categories. Out of the 60 coffee bean samples, 85% were classified as good quality while 15% were classified as poor quality. The system's great capacity to correctly identify and classify coffee bean quality and size is demonstrated by the impressive accuracy rate of 95%. These uses within the coffee business include quality control during production, sorting beans for distinct product lines, and guaranteeing consistency in flavor profiles. A helpful tool for coffee producers and processors, this method also has the ability to drastically minimize manual labor and human error in the bean grading process.

The Arabica Coffee Bean Database was generated after extracting data from the coffee bean samples. Here are the corresponding variable names in the database's columns: Area (A), Perimeter (P), Major axis length (MA), Minor axis length (MI), Aspect Ratio (AR) (Elongation), Circularity (Cr), Roundness (R), Feret Diameter (FD).

You can go back to the Morphological Features section on the introduction to take a look at the explanation of what each variable means.

4. Conclusion

The suggested method for determining the value quality of Arabica coffee beans has been successfully demonstrated in this research article. For sorting coffee beans in a farm environment, the created method provides a workable solution that may be used as a personal assistive application. The system accurately analyzes coffee bean photos and extracts crucial morphological information from the images by using a complete set of image processing and analysis algorithms. These characteristics are important markers of coffee bean quality. An SVM classifier is used to categorize the coffee beans based on the extracted features in order to verify the efficacy of the suggested strategy. The experimental findings show a high degree of accuracy, with the image processing method obtaining a remarkable 95% accuracy rate. These findings demonstrate how the proposed technology has the potential to considerably improve the accuracy and efficiency of coffee bean sorting procedures. This research advances methods for evaluating the quality of coffee beans and creates new opportunities for automation and growth in the coffee sector by utilizing image analysis techniques and the power of machine learning. The proposed approach can be improved in the future to accommodate certain coffee bean kinds and broaden its application in actual coffee production settings.

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