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# Classification and Diseases Identification of Mango Based on Artificial Intelligence: A Review

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ABSTRACT

Mango is a drupe fruit which plays an active role in the economy of different countries. Classification process is a fundamental process in: diseases detection domain, sorting and grading. Previously, farmers can detect mango's diseases, identification ripe and unripe mango by their eyes, but it is inaccurate, waste of time and effort. AI technology helping farmers get high quality agricultural crops, the essential idea of AI in agriculture is its flexibility, reliability, speedy performance and applicability. AI technology improves enterprise performance and productivity by automating processes or tasks that once required human skill. AI can also understand data on a scale that no human can achieve, this ability can bring great advantages in the field of agriculture. In this paper, a review for application of artificial intelligence in mango classification and mango diseases identification have been presented.

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## 1. Introduction.

Mango is one of the best fruits, it is a tasteful, sweet smell, seasonal fruit, there are many kinds of mango fruit which differ in shape, size, sweetness and color of skin. Mango trees are leaving and have different size(small/large), the leaves of mango are classified into: simple, incomplete and petiolate [1]. Artificial intelligence is a branch that intends to create intelligent machines, it is causing a great development and a quantum leap in agriculture by using techniques that are workable, it also helps farmers to get better and higher harvest. Artificial intelligence can provide practical, logical and effective solution for complex problems. It offers image processing, deep learning, machine learning, neural networks and expert system to classify plants [2]. Detecting plant diseases at early stages and classifying the disease are very important. Diseases identification system is essentially in diseases detection. Fungal, viral infection and bacterial diseases which can damage the crop yield by infecting the fruits, leaves and flowers, it caused several types of die back, rot, blotch, anthracnose, scab, spots, etc. so that, early detection of fruit diseases prevent massive crop loss [3,4].

The low yield of mango is due to two reasons: the disease that affecting this fruit and inexperienced farmers cannot detect mango diseases in time. Fruit sorting is significantly depending on fruits appearance, whereas grading is significantly depending on fruits quality. The process of mango sorting is fundamental in "marketing", "export" and "postharvest handling". Today, fruits classification, is important processes for

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grading and sorting mango in marketing [5]. In this work various techniques are discussed which can help new researchers in the field classification mango and identification mango diseases. This review is organized as the following: Section 2 describes mango classification system; preprocessing methods, features extraction techniques, classification algorithms. Section3 presents weaknesses and challenges of mango classification system. Section 4 concludes this review.

## NOMENCLATURE

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## 2. Classification and Diseases Identification System of Mango

Mango classification/identification system includes three main steps: image preprocessing, feature extraction, and finally classification/identification step.

### *2.1 preprocessing*

Preprocessing is the main process for any system, it performed before the process of feature extraction. It contains different processes such as: converting the input image into a grayscale image, image scaling, contrast adjustment, removing image noise. The input image which was acquired by using high resolution camera, was resized to 256x256 pixels, converted the color space then the region of interest was selected [6]. Images in [7] were acquired by using digital camera, to improve the quality of input image information some preprocessing processes were performed: resizing, image enhancement which was used to select region of interest, the system was worked in 5 seconds to detect mango diseases. A modern and effective preprocessing techniques were used in [8], the system used mango leaves images to identify if the leaf healthier, if not(diseased) the system identified disease's name.

Two cameras were used to capture images in [9], mango fruits were collected with different color and size, the images were resized, converted to gray scale and binary then segmentation methods were performed such as: edge-based algorithms, clustering technique, region-based methods and split/merge techniques. Mango leaf images were captured based on digital mobile camera in [10], preprocessing such as: cropping, resizing, noise removing and binarization were performed, to select correct ROI in diseased leaf the "K-means clustering algorithm" was used. Leaf diseases usually carried out by agriculture, in India an automated system was used to classify and identify mango leaf diseases, images were acquired using digital camera, averaging filter was used to remove noise, color transformation (RGB to HSI) and histogram equalization, image segmentation techniques were used [12].

500 images with resolution of 4320x3240 for each leaf, fruit and flower with healthy/diseased leaf's parts were captured using digital camera in [14] per-processing such as: edge enhancement, gamma correction methodology and segmentation were performed. 3500 leaf images were captured using "digital camera" and "mobile camera", the system was using to detect four diseases of mango leaf [15]. External bacteria disease in Alphonso mango was detected in [17], input images were converted into binary image then processing such as: computing histograms,

segmentation were done. In Pakistan an automated system was proposed to identify mango leaves, leaves image were captured by using digital camera, a distance of 2 feet in between mango leaf was kept with white background, all mango leaves images were captured from peak sight of white surroundings, unwanted noise was removed from image then image was converted to binary image, image enhancement was performed [19].

A novel method was developed in [20] to identify mango leaves, images of mango leaves were captured using digital scanner and stored as a JPJE type with resolution 1700* 2300, colored image was converted to grayscale, median filter was applied then image was converted to binary to perform edge detection process. Mango fruit sorting is based on color of fruit skin and fruit size, color of mango can determine if the fruit was ripe or unripe as in [23], input image was obtained using webcam and sorted as JPEG type then 11 preprocessing steps were performed. In [26] frames were collected from video signal then "deblurring wiener filter" and "pseudo median filter" were performed in order to eliminate motion blur and remove noising, image was converted to binary image, the boundary was traced then maximum axial length was found.

Mango in [27] was sorted according to its size and quality, images were captured at Venvi Enterprise with a resolution of 640*480 pixels using digital camera using natural light and white background, after that RGB and Cb of image were calculated, the edge of image was detected, the boundary was traced, the region was identified, the region with the highest boundary length was selected. Machine learning models was developed to predict the ripeness of mangoes at harvest [28], the mango is harvested from the mango field then 120 mango images were utilized, 100 for training data and 20 for testing. A. B. Alejandro et al. [29] proposed an approach to grad and sort mangoes based on their size and physical appearance. Camera with flaps, and conveyor dc motor were connected to the microcontroller to capture images. 100 images were used, some pre-processing operation were performed on input images such as: convert color image to grayscale and binary image, remove noise.

In [30] mango images were collected from trees, self-collected trees images were used then bounding box was used to detect mango image. 1200 mango images were used in [31] to classify two kinds of mango using charge-coupled device. In [32] mango was sorted and classified before exporting and packaging to the markets by evaluating mango quality. Images were captured using a CCD with a proper light intensity from a light bulb. 16,777,216 different color images were obtained, images were: resized, converted to grey-scale and binary images, the size of images was calibrated by utilizing images of ellipse. In [33] a system proposed to classify mango by evaluate the maturity of it, 10000 mango images were created using the SEEK thermal camera and smart phone camera. 75% of image were used for training, 25% for testing.

In [34] mango grading algorithm was presented, three classes of mangoes are captured: unripe, semi-ripe and ripe, the dataset was contained more than 50 samples for each class, total 400 mango images were obtained using digital camera. Number of pre-processing were performed on images: grayscale image transformation, noise elimination using median filter, segmentation using Otsu thresholding, erosion and dilation. 12 species of mango were classified in [35], 2000 samples from 12 different species of mango were captured, pre-processing steps such that:

resizing, labelling of species and scaling were performed. Another approach [36] used for mango grading, mango was classified into: healthy, disease, ripe, unripe, big, medium, very big. 748 samples of mangoes were captured from significant database, the samples were divided into: 169 healthy images, 34 diseased, 192 ripe, 164 unripe, 97 belong to big mango, 41 belong to medium mango and 49 belong to very big mango then pre-processing like: image resizing, noise removing, image segmentation and dilation /erosion were performed.

381 samples were used in [37] to classify mango into rapid and unrapid. In [38] an approach was developed for mango classification and grading of 8 species, mango images with white background were resized to 280 ×260, preprocessing such as: rotation, translation, zooming, shearing, and horizontal flip were performed, 2400 samples were used for classification and 600 samples for grading. Table 1. summarizes the image acquisition, image dataset and image pre-processing steps.

**Table 1- Summary of image acquisition, image dataset and image pre-processing steps**

| Ref. | Image Acquisition Device | Dataset Size | Pre-processing method |
|---|---|---|---|
| S.Raj Kumar and S.Sowrirajan[6] | High Resolution Camera | Not Reported | Grayscale Image Transformation, Scaling, Contrast Adjustment, Removing Image Noise |
| Veling S. S. et al. [7] | 8 Mega Pixel Camera | 92 | Resizing, Image Enhancement |
| Priyadharshi ni M. K et al. [8] | Not Reported | 100 | No Preprocessing Used |
| Dhameliya S.et al. [9] | Two Cameras | 600 | Resizing, Gray Scale and Binary Transformation, Edge Detection Clustering, Region-Based Methods and Split/Merge |
| Sethupathy J. and Veni S. [12] | Digital Camera | 25 | Remove Noise, Color Transformation (Rgb To Hsi), Histogram Equalization, Segmentation |
| S. B. Ullagaddi and S.Viswanadha Raju[14] | Nikon 16MP Digital Camera" In [14] | 500 | Edge Enhancement, Gamma Correction Methodology |
| Sampada Gulavnai and Rajashri Patil [15] | Sony Digital Camera and Mobile Camera | 3500 | No Preprocessing Reported |

| | | | |
|---|---|---|---|
| Amritha S Nadarajan and Thamizharasi A. [17] | Digital Camera | 100 | Binary Image Transformation, Histograms, Segmentation |
| Maqbool I. et al. [19] | 8 Mega Pixel Digital Camera | Not Reported | Binary Image, Image Enhancement |
| Lakshmi Dutta and Tapan Kumar Basu.[20] | Digital Scanner | 80 | Converted to Grayscale and Binary Image, Edge Detection |
| Yossy E.H. et al. [23] | Webcam | 52 | Rgb And Hsv Transformation, Color Segmentation, Image Morphology Processes, Scaling Thresholding, Find Contours of Image. |
| Nandi C.S. et al. [26] | Video | 16 400 | Eliminate Motion Blur and Remove Noising, Binary Transformation, Boundary Tracing Then Maximum Axial Length Was Found |
| Tomas U. Ganiron Jr. [27] | Camera "Canon Digital IXUS 400 | 140 | Edge Detection, The Boundary Was Traced, The Region Was Identified, The Region with The Highest Boundary Length Was Selected |
| Denchai W. *et al.* [28] | Digital Camera | 120 | Not Reported |
| A. B. Alejandro et al. [29] | Digital Camera | 100 | Convert Color Image to Grayscale and Binary Image, Remove Noise |
| P. Borianne [30] | Digital Camera | 10,000 | No Pre-Processing Used in Their Study |
| A. S.A. Mettleq [31] | Charge-Coupled Device | 1200 | Not Reported |
| N.T.Thinh [32] | Digital Camera | 16,777,216 | Resized, Converted to Grey-Scale and Binary Images |
| V. Bhole[33] | SEEK Thermal Camera and Smart Phone Camera | 10000 | Not Reported |
| A. M. Vyas [34] | Camera (Nikon DSLR). | Total 400 | Grayscale Image Transformation, Noise Elimination Using Median Filter, Segmentation Using Otsu Thresholding, Erosion and Dilation |

| | | | |
|---|---|---|---|
| S. Girish [35] | Kaggle, Mendeley, Github Image Database | 2000 | Resizing, Labelling of Species, Scaling, Train-Test Split and Calculate Bottleneck Layer |
| M. K.Tripathi [36] | From the Internet | 748 | Image Resizing, Noise Removing, Image Segmentation and Dilation /Erosion Were Performed on Mango Images |
| D. Worasawate. et al. [37] | Parallel plate capacitor sensor | 120 | SMOTETomek was used for cleaning and balancing the data |
| H. M. R. Iqbal and A. Hakim [38] | Nikon 7000 camera | 2400 for classification, 600 for grading | T ranslation, rotation, zooming, horizontal flip and shearing |

## *2.2 Feature Extraction Process*

Feature extraction is fundamental step that includes extraction of characteristics from input image, features extraction process aims to extract significant, correct and unique features that can distinguish an input image from others. Two kinds of features can be extracted from image: first type is shape-based features which describes the whole object, the second type is the geometric-based features which describes the local features of object. Some of approaches used hybrid features as in [6]: texture, color, and geometric features were extracted from input image. Hybrid features used again in [9], shape features and color features were extracted from mango image. Textural features based on GLCM and spatial gray-level dependence matrices were used in [12] to identify and classify the diseases of mango leaves in Indian.

Combination of "Wavelet-PCA based statistical features" and "modified rotation kernel transformation based directional features" were used in [14] to extracted features from mango leaf, flower and fruit in order to diagnose of pathological problems in mango. Combination of shape features and RST-Invariant features of mango leaf were extracted in [19] to identify mango. Two features: geometric features (width, area, diameter, mango perimeter) and morphological features (narrow factor, form factor, aspect ratio, rectangularity, smooth factor, ratio of mango perimeter) were extracted to detect ripe and unripe mango [24]. Geometrical features of mango leaves like: length, aspect ratio, width with morphological features were obtained for 80 sample images in [20] to identify the type of a mango tree. Shape and texture features were extracted from mango image in [21] to classify mango in Pakistan.

A gain the ripe or unripe mango was detected based on color features which were extracted from mango images [23]. Textural features were used to describe infected part in [7,8], the GLCM method was used to characterize the texture of an image in order to classify mango diseases. Textural features were extracted again in [18], 9 different features were extracted from mango image (1766 images) to develop automated system capable of classifying different types of mango. Eight features (area, solidity, diameter, extent, convex area, number of objects, and major axis length) were extracted from leaf image to classify mango leaf diseases [10]. Color features were extracted in order to identify normal or diseased mango [17]. (13) number of features were extracted based on GLCM from 30 images in [22], the system successfully classified 10 kinds of mango fruits. Sorting of mangoes into number of classes is requisite in mangoes harvesting process, 27 features were extracted in [26] to sorting mango according to its maturity.

Mango in [27] was sorting according to its size and quality, features like: area, perimeter, percent defect and roundness were extracted, area and perimeter were used to determine the size of the mango whereas percent defect and roundness were used to determine the quality of the mango. Features included physical, biochemical and electrical attributes were extracted in [28], 10 attributes such as: green color, weight, red color, TSS, blue color, TSS–TA ratio, weight and capacitance ratio, TA, voltage and capacitance were extracted. In [29] color, black spots and area were extracted, probabilistic neural network was used to classifying mangoes into three classes (small, medium, large).

A region of interest pooling was performed in [30] using mango features that extracted by the convolution neural network, Faster R-CNN network was used for identification and detection processes, 7000 images used for validation, 3,000 for testing, the results of validations showed that undertake additional relaxion was necessary for more R-CNN Faster network relevant predictions respected to users' expectations. A gain in [31] an approach used to classify two mango species, the data set that used was contained 1200 samples, 90% of it used for training, 10% for validation, the training accuracy was 100%. In [32][33] a system was designed to evaluate mango quality and maturity based on mango shape features, mango was classified in terms of volume, density, color, shape, size and maturity into three classes according to mango quality: extra Class-I, and Class-II. In [34] color and size features were extracted, mango was classified into four types: unripe, semi-ripe, ripe or rejected based on the extracted features with 10 grading rules.

In [35] CNN with transfer learning used to classify mango, 2000 mango samples were used, 80% of samples for training and the rest samples 20% for testing and validation. In [36] shape, texture and color features were extracted then lion assisted firefly algorithm was used to select relevant features, the selected features fed to CNN, at last mango category was identified. Ten features from three types of features: physical features, electrical features and biochemical features were extracted in [37] then fed to machine learning for classification. In [38] texture, color, shape, and size features were extracted then fed to convolutional neural network in order to classify and grade mango. Table 2. bellow summarizes the features and advantages.

**Table 2- Summary of the features, advantages**

| Ref. | Features | Advantages |
|---|---|---|
| Veling S. S. et al. [7] | Textural features | Effective mango diseases classification performance |

| | | |
|---|---|---|
| Prakash B. and Yerpude A. [10] | Shape features | compliant feature selection and high accuracy diseases identification |
| S. B. Ullagaddi and S.Viswanadha Raju[14] | Wavelet-PCA based statistical features" and "modified rotation kernel transformation based directional features | An accurate system capable of classifying mango based on various parts (fruit, leaf, flower) with high accuracy |
| VaniAshok and D.S.Vinod[18] | Textural features | good results of detection defects in mango |
| Maqbool I. et al. [19] | Shape features and RST-Invariant features | Achieve good results |
| Behera S.K. et al. [22] | GLCM | Better accuracy for classifying different kinds of mango fruits |
| Yossy E.H. et al. [23] | Color features | good capability for color texture analysis |
| Chhabra M. et al. [24] | Geometric features and morphological | Robust features & achieve good results |
| Nandi C.S. et al. [26] | GLCM | Reliable and adequate method for sorting mango according to its maturity |
| P. Borianne [30] | Features extracted by CNN | Achieves good results on both identification and detection based on Trees images |
| A. S.A. Mettleq [31] | Shape features | Achieve high accuracy |
| V. Bhole[33] | Features extracted by CNN | workable feature selection and high classification accuracy |
| A. M. Vyas [34] | Color and size features | privileged capability for shape analysis and size of mango |
| S. Girish [35] | Features extracted by CNN | Achieve high accuracy |
| M. K.Tripathi [36] | Shape, texture and color features | Robust features & achieve good results for mango grading |

| | | |
|---|---|---|
| D. Worasawate. et al. [37] | physical features, electrical features and biochemical features | Achieve good results |
| H. M. R. Iqbal and A. Hakim [38] | texture, color, shape, and size features | achieve good accuracy for mango classification and grading |

## *2.3 Classification Process.*

In this section various studies of mango identification and classification are illustrated in Table 3.

**Table 3- Summary of various studies of mango fruit.**

| Researcher name | Aim of research | Classification Algorithm | Organ | Accuracy |
|---|---|---|---|---|
| Sutrodhor N. et al. [4] | Mango Leaf Ailment Detection | Neural Network and support vector machine | Leaf | 87.5% |
| Aboalarbe M. S. and Adl A. [5] | Classifying mango diseases | Machine learning and deep learning algorithms | Leaf | 97% |
| S.Raj Kumar and S.Sowrirajan[6] | Mango diseases detection | Hybrid features with Lloyd's clustering and BPN classifier | Leaf | Not reported |
| Veling S. S. et al. [7] | Classifying mango diseases | support vector machine | Fruit and leaf | 90% |
| Priyadharshi ni M. K et al. [8] | Identifying mango diseases | Deep learning technique | Leaf | Not reported |
| Dhameliya S.et al. [9] | Volume estimation of mango | computer vision system | Fruit | 80% |
| Prakash B. and Yerpude A. [10] | Identifying mango diseases | Back Propagation Neural Network | Leaf | 94% |
| | | Expert system | Fruit | Not reported |

| | | | | |
|---|---|---|---|---|
| Elqassas R. and Abu-Naser S.S. [11] | Detection of mango diseases | | | |
| Sethupathy J. and Veni S. [12] | Identifying mango diseases | Support Vector Machine, Artificial Neural Network | Leaf | Not reported |
| S. B. Ullagaddi and S.Viswanadha Raju[14] | Diagnose of pathological problems in mango | Wavelet-based principal component analysis, rotating kernel transform with artificial neural network | Flower Fruit Leaf | 98.50%, 98.75%, 98.70% |
| Sampada Gulavnai and Rajashri Patil [15] | Detection of mango diseases | Deep learning neural network | Leaf | 91% |
| S. B. Ullagaddi and S.Viswanadha Raju[16] | Detect black spots disease | Artificial neural network | Leaf and fruit | 98% |
| Amritha S Nadarajan and Thamizharasi A. [17] | Detection of bacterial disease | Color features with a template matching algorithm | Fruit | Not reported |
| VaniAshok and D.S.Vinod[18] | Detect Defects in mango | Textural features with neural network | Fruit | 90.1% |
| Maqbool I. et al. [19] | Identify Mango Leaves | Shape, morphological features artificial neural network | Leaf | 96% to 98% |
| Lakshmi Dutta and Tapan Kumar Basu.[20] | Classify mango trees | Geometrical features with artificial neural network | Leaf | Not reported |
| Abbas Q. et al. [21] | Classify mango | Principal Component Analysis, Linear/ Nonlinear | Fruit | 83% |

| | | | | |
|---|---|---|---|---|
| | | Discriminant Analysis techniques | | |
| Behera S.K. et al. [22] | Classify mango | Statistical Feature and Multi class support vector machine | Fruit | 90% |
| Yossy E.H. et al. [23] | Mango sortation | Computer vision and artificial neural network | Fruit | 94% |
| Chhabra M. et al. [24] | classify ripe / unripe mango | geometric, morphological features with neural network | Fruit | 95.5 % |
| Zheng H. and Lu H. [25] | Classify browning mango | Fractal dimension, least square support vector machine | Fruit | 85.19% to 88.89% |
| Nandi C.S. et al. [26] | Mango sorting | Support vector machine and Recursive features elimination method with Machine Vision | Fruit | 96% |
| Tomas U. Ganiron Jr. [27] | Mango sorting | Area, perimeter, percent defect and roundness with nearest neighbor technique | Fruit | Not reported |
| Denchai W. et al. [28] | Predict the ripeness of mangoes at harvest | of biochemical, physical, and electrical properties, green color, weight, red color, TSS, blue color, TSS–TA ratio, weight and capacitance ratio, TA, voltage, capacitance with Machine Learning Methods | Fruit | The GNB, and SVM, and FANN models had average accuracies of 73.0%, 75.0%, and 85.0%, respectively |
| A. B. Alejandro et al. [29] | Grad and Sort mangoes | Color, black spots and area with probabilistic neural network | Fruit | 87.5% |
| P. Borianne [30] | Identify and detect mango | Faster R-CNN network | Trees | 90% for detection |

| | | | | |
|---|---|---|---|---|
| | | | | 56% for identification |
| A. S.A. Mettleq [31] | Classify mango | CNN | Fruit | 100% |
| N.T.Thinh [32] | Sort and Classify | AI | Fruit | Not reported |
| V. Bhole[33] | Classification | CNN | Fruit | 92.27 % |
| A. M. Vyas [34] | Grading | Color, size features with Ten grading rules | Fruit | 94.97% |
| S. Girish [35] | Classification | CNN | Fruit | 97.6% |
| M. K.Tripathi [36] | Grading | CNN | Fruit | 92% |
| D. Worasawate. et al. [37] | Classification | machine learning | Fruit | 89.6% |
| H. M. R. Iqbal and A. Hakim [38] | Classification and Grading | CNN | Fruit | 99.2% classification and 96.7% grading |

## 3. Weaknesses and Challenges

Most researchers use images of fruit or leaf with a plain background, while few use images of whole mango trees or images with a complex background [14,16]. An extra effort needs to be made on extracting mango images from trees or video movie. Researches [12,20,23] need to increase number of images in order to improve classification accuracy. Most researchers based on images taken from the internet or by using a digital camera, while it is better to use a scientific database to get better results. Distinguishing mango from another based on their shape is a challenge because most mango fruits are different in size, color, and even shape from one country to another, and sometimes even in the same country. So, it is better to adopt additional features with shape features. Some of approaches using deep learning or neural network to improve the performance of classification by modified number of nodes or number of neural layers, this is challenging, how to find out the ideal number of nodes and layers.

It is important to have good experiences for choosing correct values for nodes and layers. In [26] the algorithm takes a long training time and misclassification happen when black spot appears on mango. In [27] mis-identification of the stem was occurred since it can be brown or green. The green stem represents healthy whereas the brown stem represents defective. In [30] the cross validations explained the need to pledge extra improvements to make the predictions of the R-CNN more pertinent to users' ambition. Some studies did not mention details of: image collection or database used [6,19], accuracy rate of their work [6,8,11,17,20,27,32]. Approaches [9,21,25,28,29] need to increase number of key parameters to improve accuracy rate.

## 4.Conclusion.

This paper reviewed the various techniques of mango diseases identification, mango classification. New researchers can base on this review to make a comparison between their results and the previous results. Number of methods were discussed for pre-processing stage: resizing, grayscale and binary image transformation, scaling, noise removing, image morphology processes, edge detection, segmentation, erosion/dilation and boundary tracing. Digital camera is used to capture images, most approaches used single digital camera whereas one approach is used two cameras. Most mango grading and sorting automated systems are based on mango fruit whereas mango diseases detection systems based on leaves of the mango.

In feature extraction stage features are classified into: textural features, shape features, rst-invariant features, color features, geometric features and morphological. Textural features, shape features, and color features are the most commonly used. In classification stage neural network, support vector machine, machine learning, deep learning algorithms, faster R-CNN network, CNN, probabilistic neural network, and computer vision were used. Wavelet-based principal component analysis with artificial neural network and CNN achieved high accuracy of 98.75%,100% respectively whereas GNB and SVM methods achieved low accuracy of 73.0%, 75.0% respectively.

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