Research article

Eng. Cov & Innov. An Int. J. Volume 01, Issue 01, January – April, 2026, ISSN 3108-1843 (online)

Universal Research Forum

Engineering Convergence and Innovation (ECI) An International Journal

www.universalresearchforum.com

Classification of Papaya Fruit Maturity Level Using Image Processing

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Published Date: 21 October 2025.

ABSTRACT

Computer vision has seen great developments in the recent past, and they have facilitated broad applications across all aspects of life. One of the areas of application is classification of fresh produce, however, classifying vegetables and fruits has proven to be a challenging endeavour and requires careful construction. Fruit and vegetable classification is a challenging problem because it has similarities across classes and non-regular intraclass features. To create a papaya fruit classification system for evaluating quality, however the state-of-the-art has only been created for a restricted number of classes and datasets. Optimize algorithms for speed and efficiency, enabling real-time analysis in applications like surveillance or autonomous driving. Accurate high-quality, representative datasets and use data augmentation to improve robustness. To overcome the challenges of the CNN model proposed the model named YOLO v8 which provides the solution for different classification methods The goal of this study is to determine the status of papaya fruit, like matured, partially(semi) matured or unmatured. The model that was trained accomplished a precision recall accuracy as 98.2% and precision confidence achieved is 94% proving that this strategy is feasible. As per the results classification of mature, semimature and unmature results are 91%, 98 to 99%, 93 to 94 % respectively as improved compared with existing model.

Keywords – *CNN, Deep Learning, Image Processing,* Papaya Fruit, *YOLO v8.*

1. INTRODUCTION

Papaya is well-known for being a delicious tropical fruit that grows in warm climates and is extensively found around the world. India produces more papayas than any other country in the world, with five million tons produced in 2013. Carica papaya is its scientific name, and it grows on an evergreen tree that is between two and ten meters above the ground. The leaves of the papaya tree are flat and form a crown from the top, and the lower leaves begin to fall as the tree ages. The stem of the papaya tree is hollow and relatively soft, and the fruit is known for its sweet flavour, glossy appearance, and ease of inclusion in meals.Besides, papaya fruit provides a lot of advantages to the human body like, eliminating the threat of diseases like heart attack, diabetes, cancer and help in keeping hair and skin healthy. Papayas get ripened quickly at room temperature with the help of paper bag. If the fruit is not properly stored, it will turn extremely mushy within minutes after being ripe. Typically, any of us glance at a papaya image, observer will be able to identify what it is fairly easily. It's not so simple for computers, to "see" images differs from humans. Machines that use deep learning concepts find it difficult to classify images. Through image classification, a computer can analyze papaya images and identify which "class" they belong to [1]. Computers would examine photos pixel by pixel in the early days of image categorization, which was based on raw pixel data.

The problem is that two images of the same object may appear very different. Various backgrounds, viewpoints, attitudes, and other elements may be used in their capture. Computers found it challenging to correctly "see" and classify images as a result. As image categorization becomes more reliable, it has a few uses and enormous potential. External influences such as exhaustion, retaliation, and prejudice can cause errors in the visual appraisal of fruit quality and classification [2]. Determining a fruit's maturity stage affects both the quality of the food and the amount of time it should be stored before consumption. It takes a lot of time and is damaging to estimate these properties with human operators' help. Therefore, in this sector of application, quick, clever, and non-destructive technologies are required.

1.1 Process Distribution of Fruit Classification:

Fruit detection is a crucial feature of contemporary farming techniques. Being able to efficiently and effectively identifying and evaluate the ripeness of fruit is a fundamental step in optimizing farming operations, improving crop yield and quality of fruit. Fruit detection technology has been under the spotlight in recent years with its potential to transform the agricultural sector [3].

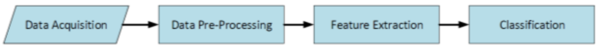


Fig 1. Process distribution of fruit classification.

Data acquisition in image processing (Fig 1) refers to the process of capturing and gathering image data for further analysis and processing. It involves various methods and technologies to obtain high-quality images that can be used for a varied range of applications [4].

Data preprocessing in image processing shall define as the sequence of methods and procedures used to ready raw image data for processing and analysis. This is a critical process because the quality of input data directly affects the performance of any image analysis, feature extraction.

Feature extraction is a precarious process in image processing and computer vision that involves identifying and quantifying key attributes from images. These features are used to represent the image in a way that makes it easier to analyze, classify or recognize objects and patterns within the image. Effective feature extraction can significantly enhance the performance of subsequent tasks such as classify, segmenting and object detection.

Classification in image processing refers to the process of assigning labels or grouping to images depend on their content. This step is essential for different applications, which includes object recognition, medical diagnosis and scene understanding. Classification can be performed using traditional machine learning techniques or more advanced deep learning methods, YOLOv8 model. Image processing play a crucial role in the field of fruit classification, enabling automated systems to identify and categorize various types of fruits based on their visual characteristics. This application combines techniques from computer vision, machine learning and artificial intelligence to enhance accuracy and efficiency in tasks that traditionally relied on manual inspection.

1.2 Digital Image Processing Model:

This model involves the manipulation of digital images through algorithms and techniques to enhance, analyse or transform them. Here are some key concepts and techniques in the field shown in Fig 2.

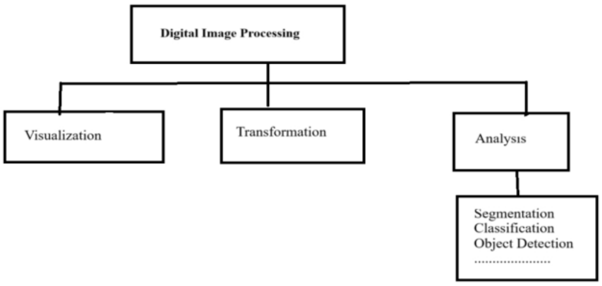


Fig 2. Digital Image Processing

Visualization in digital image processing referred to the techniques and methods used to represent and interpret image data visually. It plays a crucial role in understanding and analysing images, enabling users to extract meaningful information, identify patterns, and make informed decisions based on visual cues.

Transformation These transformations can change the spatial domain of an image, manipulate pixel values or alter its geometrical properties. It shows a essential role in many uses, containing image enhancement, analysis, & compression.

Image analysis refers to the method of extracting meaningful info from images through various techniques and algorithms. It involves interpreting the visual content of images to identify patterns, detect objects, and extract features for further processing or decision-making. Image analysis is a critical component of many applications across various areas such as medical imaging, remote sensing and computer vision.

1.3 YOLO V8 Suite for Image Processing:

YOLOv8 (version 8) is a hi-tech real-time object detecting model that extends the accomplishments of earlier variants (Fig 3). It's configured to operate with high accuracy and speedy processing rates, henceforth appropriate for numerous applications like fruits, surveillance, autonomous driving and robotics etc.

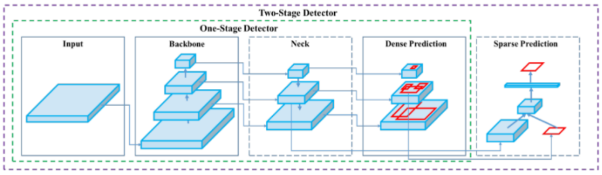


Fig 3. Object Detector Anatomy

The latter begins the initial step with choosing multiple proposals, followed by the second step of conducting prediction on the proposed areas. Instances of two-stage detectors are the renowned R-CNN variants like Fast R-CNN and Faster R-CNN, which have higher accuracy nonetheless poor computational efficiency. The second converts the job to a regression problem such that there is no need for a pre-stage to find candidate regions; hence, prediction and candidate selection are done in one pass. Consequently, architectures under this category are less computationally intensive, producing greater FPS and detection speed, but overall the accuracy is worse compared to two-stage detectors [5].

YOLOv8 utilizes a special CSPDarknet53 backbone with cross-stage partial connections to boost accuracy and facilitate better information transfer across layers. To capture information at multiple scales, the neck, or the feature extractor, aggregates feature maps of different backbone stages. YOLO module employs higher-level semantic features and low-level spatial details to enhance identification precision, especially for small objects. YOLOv8 makes bounding box predictions based on many detection modules. The ultimate detections are then achieved by averaging the predictions.

2. LITERATURE WORK

Investigators from all over the world have done research on identifying maturity of papaya fruit using many models. Some of the research results have been listed here. The advancement of technology and science in digital image processing enables automatic processing of agricultural and plantation products through the use of image processing software [6]. Thus, digital image processing technology is employed to measure the ripeness level of the papaya fruit with increased accuracy and efficiency. This work is to develop an artificial intelligence model for papaya farmers in deciding on the level of maturity of Farmers tend to rely on their intuition during harvesting papaya for determining the fruit which is ripe, half-ripe, or unripe. This intuition is the tacit knowledge [7] of the farmer, a hands-on and intuitive skill acquired cumulatively through years of trial-and-error experience while harvesting. Dependent on implicit knowledge, naturally, farmers will have numerous constraints at the plot level, so this intelligence has to be transferred to machines. Al-Araj et. al. [8] have discussed maturity status of papaya fruits classification using ML and transfer learning technique, authors proposed two ML and transfer learning-based approaches for fruit maturity classification. The VGG19 was trained with an accuracy of 100% and training time of 1 min 52 s.The authors modified the Red-Green-Blue Depth image-based methodology used by Al-Atrash et al. [9] Alghoul A. et al. [10] researched image-based detection of diseases of tomato leaves with deep learning. The authors were able to get a high accuracy rate in identifying the five tomato disease. Al-Kahlout, et al. [11] introduced the lightweight SM-YOLOv5 algorithm for detection of tomato fruits in farm. The approach utilizes an optimized YOLOv5 structure modified specifically for resource-saving detection of tomatoes. It is very accurate yet computationally light. Its limitation of specialization for the detection of tomatoes might restrict its use in other fruit or plant types. The paper also does not contain comprehensive experimentation and verification across different datasets and real-world environments. Nevertheless, the lightweight SM-YOLOv5 presents a hopeful method of efficient detection of tomato fruits in the context of plant factory environments. GAO et al. [1] emphasized pineapple fruit finding and localize in real-world atmosphere based on binocular stereo vision and an improved YOLOv3 model. The approach integrates depth from the stereo vision with the enhanced YOLOv3 model for detection of pineapple. The approach, though, is restricted to applying itself mainly to detect pineapple and could not generalize effectively to other fruits or environments. Also, the paper is without comprehensive validation of a diverse range of natural conditions and environments. Alkronz, et al. [12] work in representing a promising improvement for pineapple fruit detection in natural environments, demonstrating the potential of marrying computer vision and deep learning methods.

Available literature survey shows that less works has been concentrated on classification of papaya, hence, this work mainly concentrating on classify the papaya using deep learning and YOLO v8 model.

3. METHODOLOGY

This chapter describes about the existing methods, proposed method and process method and benefits, application and single stage detector.

3.1 Deep learning

Deep learning is a procedure of ML that is redefined as a starting point for the solution of another problem with the knowledge gathered from a standing model. In the present research, the pre-trained convolutional neural network (CNN) method under transfer learning were finetuned. papaya fruit ripeness state classification model using a deep learning methodology.

The effectiveness of pre-trained networks in classifying papaya fruit development stages is evaluated. VGG16 is the pre-trained network. Because the VGG network simply uses three convolutional layers stacked one on top of the other in ascending depth, it is incredibly simple. Max pooling is used to minimize volume size. Applications including image classification, object recognition, recommendation systems, and occasionally natural language processing are the main focus of deep CNNs. DCNNs' power lies in their individual layers. It makes use of 3-d NN. Process the image's RGB components all at once. Convolution, pooling, activation, and fully linked are the four types of layers that make up a convolution network's architecture.

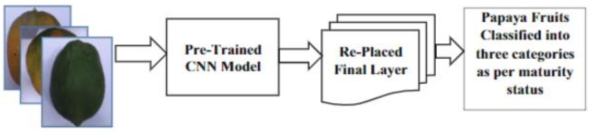


Fig 4. Papaya classification step using CNN model

A. Convolution layer

- A convolution: accepts a set of weights and multiply the weights with the inputs of the NN.
- Kernels or filters: it sweep across an image several times by the multiplication operation.
- Convolution and dot product: a mathematical process carried out by the convolution. Every filter has multiplied the weights against different input values. The total inputs are added up.

B. ReLU Activation Layer

A Rectified Linear Unit: Convolution maps are fed into a non-linear activation function, which, if the input is positive, outputs the input; if not, it outputs zero. All of the filtered image's negative values are removed in this layer and replaced with zero.

C. The pooling layer

Utilized to reduce the spatial dimensions, but not the depth, on a CNN model, shrink the image size and retain only crucial information. Reducing parameter numbers and calculations in the network assist pooling layers in preventing overfitting.

D. Fully Connected Layer

Each dependent non-linear function in a neural network (NN) is made up of a neuron. Over the course of a weight's matrix, the neuron in the fully connected layers transforms the input vector linearly.

Data Collection: A dataset from Roboflow resources was employed in the study to support the fruit detection investigation. The model was trained and tested using the dataset, which is a diverse collection of fruit photos. A diverse collection of fruit photos with a wide range of variations in size, shape, color, and environmental circumstances are included in the dataset. The purposeful incorporation of the varied instances is essential in order to establish the scalability of our proposed model. Scalability, for purposes of this research, is the capability of a model to generalize well across a very extensive set of scenarios and conditions. With the inclusion of a large number of different fruits and their corresponding features, the Roboflow dataset guarantees the model is learning from a detailed level of real-world conditions. Class balance within a dataset indicates the spread of samples over varying categories. In the dataset context, class balance indicates whether the proportion of images belonging to each class is roughly equal or not, in other words, whether there is a large imbalance (Fig 5).

Morphology is a branch of image processing that dealing with the thing's shape & structures in an image. It involves the application of various operations that process images based on their geometric structures. Morphological techniques are particularly useful for analysing and manipulating binary images but can also be applied to grayscale images.

Framing created a custom dataset of 254 image, the medium image size if 640 X 640, If the image is too small or big it will resize to the size of 640 X640 as required.

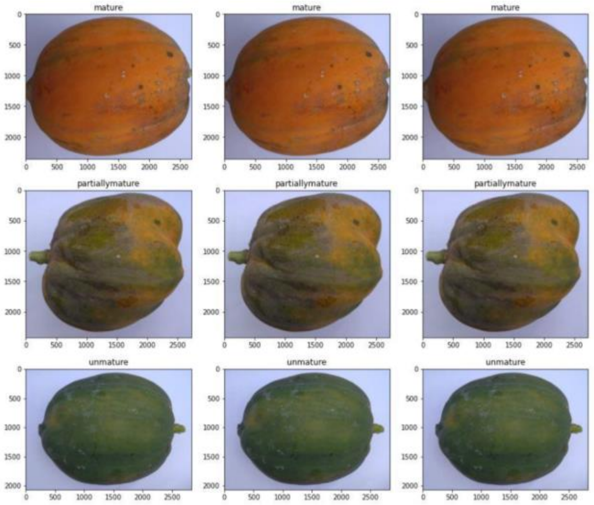


Fig 5. Samples of dataset collected

3.2 Pre-trained model for papaya fruit:

YOLOv8 excels in identifying and classifying objects within images. Applying YOLOv8 to papaya classification involves using its capabilities to detect and classify papayas from images effectively. Here's a detailed explanation of how YOLOv8 can be utilized for this task:

Real-Time Performance: YOLOv8 designed for high-speed object detection.

Single-Stage Detection: Unlike traditional detection frameworks that involve multiple stages, YOLO processes making it efficient.

Result: Display the result based on the classification mature, semi mature and unmature.

- **Mature:** Fully ripe fruits with a yellowish hue.
- **Semi-Mature:** Fruits that are transitioning from green to yellow, often with some green patches.
- **Unripe:** Green fruits that are not yet ready for consumption.

4. RESULTS AND DISCUSSION

This section deals with results obtained from CNN and YOLO v8, in this work, papaya fruit is classified as mature, semi-mature and unripe. While comparing CNN (Convolutional Neural Networks) and YOLOv8 it's important to note that they serve different purposes and have distinct characteristics as shown in Table 1.

Table 1: Comparison results of CNN model and YOLO v8 Model

Particulars	Existing System	Proposed System
Data Set	Fruit 360	Fruit 254
Collected Data Set	Kaggle	RoboFlow
Model	CNN	Yolo v8
Image Size	150X150	640 X640
Training Accuracy	92.97	95.3%
Testing Accuracy	85.12%	76.81%

For assessing a YOLOv8 model's effectiveness in fruit detection, precision, recall, precision-confidence, and F1 score curves are essential.

Table 2: Results based on the classification

Maturity Levels	Accuracy Values
Mature	91%
Semi Mature	98 % - 99%
Unmature	93% - 94%
Precision Recall	98.2%
Precision Confidence	94%

Precision indicates confidence expresses the balance between confidence bounds and precision and the F1 score compromises between precision and recall (Table 2).

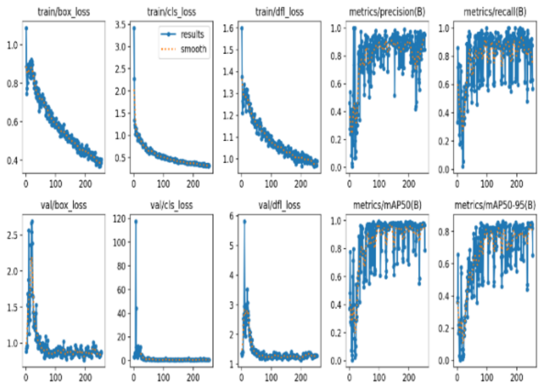
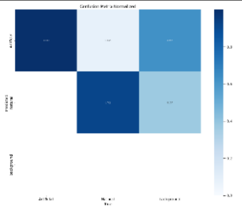
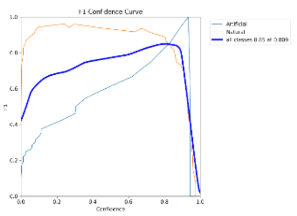


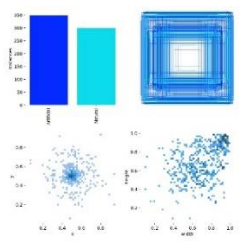
Fig 6. Performance Analysis and validation.



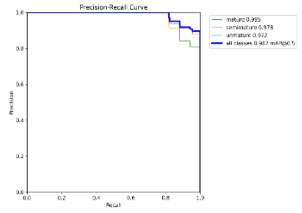
(a) confusion matrix



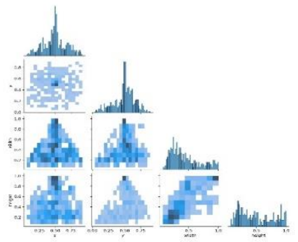
(b) F1 Confidence curve



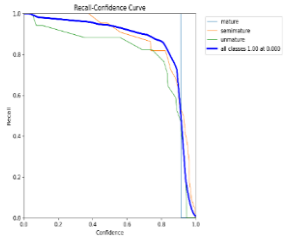
(c) Scatter graph



(d) Precision Recall curve



(e) correlation graph



(f) Recall Confidence curve

Fig 7. Graphs and analysis

Figure 6 represents performance analysis and validation of this proposed work. Figure 7 depicts various graphs plotted from results obtained by this work. Results obtained from this work are efficient and satisfied, maturity 91%, semi-mature 98 to 99% and unmature 93 to 94%. Also, this work resulted 98.2% and 94% for precision recall and precision confidence respectively.

5. CONCLUSION

Numerous Several approaches have been investigated in the literature to solve this fruit detection problem. This research employed a deep learning model founded on the YOLOv8 architecture for solving this problem. Using a custom dataset, it thoroughly performed model training, validate and testing. The experimental outcomes and performance analysis attested to the effectiveness of this said method, proving how it can deliver high accuracy at high rates, hence promising great improvements in papaya fruit detection in the agricultural sector. Results acquired from this research are effective and satisfactory, maturity 91%, semi-mature 98 to 99% and unmature 93 to 94%. Moreover, this research yielded 98.2% and 94% for precision recall and precision confidence respectively. Given these constraints, the future direction of research can aim towards solving these issues. More efficient deep learning architectures that are specifically designed for fruit detection can reduce the resource burden. Additionally, investigations into methods like domain adaptation and transfer learning to improve generalization in different conditions and among different types of fruit may result in more resilient and flexible fruit detection systems. These initiatives would dramatically increase the utility and potency of fruit detection method in agriculture detection technology in agriculture.

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