JOURNAL OF EMERGING TECHNOLOGY AND DIGITAL TRANSFORMATION
ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)

INTELLIGENT FRUIT SORTING, SEGREGATION, AND QUALITY CONTROL FOR SMART FARMING SYSTEMS

***Muhammad Sajjad**
School of Computer Sciences, Minhaj University Lahore, Punjab, Pakistan
Imran Akhter
School of Software Engineering, Minhaj University Lahore, Punjab, Pakistan
Humaira Bibi
School of Computer Sciences, Minhaj University Lahore, Punjab, Pakistan.
Muhammad Usman
School of Computer Sciences, Minhaj University Lahore, Punjab, Pakistan
Adeel Khan
School of Computer Sciences, Minhaj University Lahore, Punjab, Pakistan
Abdul Jabbar
School of Computer Sciences, Minhaj University Lahore, Punjab, Pakistan
Mehma Kanwal
School of Computer Sciences, Minhaj University Lahore, Punjab, Pakistan.
Zarka Saeed
School of Software Engineering, Minhaj University Lahore, Pakistan

RECEIVED	ACCEPTED	PUBLISHED
12 June 2025	19 June 2025	27 July 2025

Abstract:
Fruits are a mainstay of a healthy diet. They keep our bodies healthy because they contain minerals, vitamins, fiber, and water. Manpower is required for the segregation of the fruits to maintain their quality. A lot of time is wasted on segregating fruits to maintain quality. Due to the poor quality of fruits, farmers are facing a huge loss in their agricultural fields. Automation enhances the quality of the fruits and speeds up the segregation process by ensuring accuracy and efficiency. Many Algorithms have been developed by researchers for the segregation of fruits. The proposed Deep learning model YOLOv11 will segregate (Healthy or Rotten) the fruits into their specific classes, ensuring the quality by processing the images of the fruits, gaining validation Accuracy of 97.91%. This study fills the gap between agriculture and technology. It represents the potential of AI in food quality inspection processes.
Key points: Fruits Detection, Classification, Segregation, YOLO (You Only Look Once), Deep Learning, Computer Vision.

Introduction

Fruits and vegetables are essential components of our daily food intake because they provide us with vitamins and fiber. The Vitamins and fibers play a vital role in our lives. They keep our body healthy and strong [1]. For example, citrus fruits contain vitamin C, which helps improve our immune system. Bananas are a high source of energy and potassium for our bodies. They offer us strength and strengthen our digestive system. Fruits are nature's gift to humans and are available in many flavors. A variety of fruits and vegetables are available in the world. The food industry depends on fruits and vegetables. The quality of fruits is more essential for the quality of food products because healthy fruits contain more vitamins and minerals compared to rotten fruits [2]. Rotten fruits can produce diseases in humans. Fresh fruits are used in the industry to make delicious food items [2].

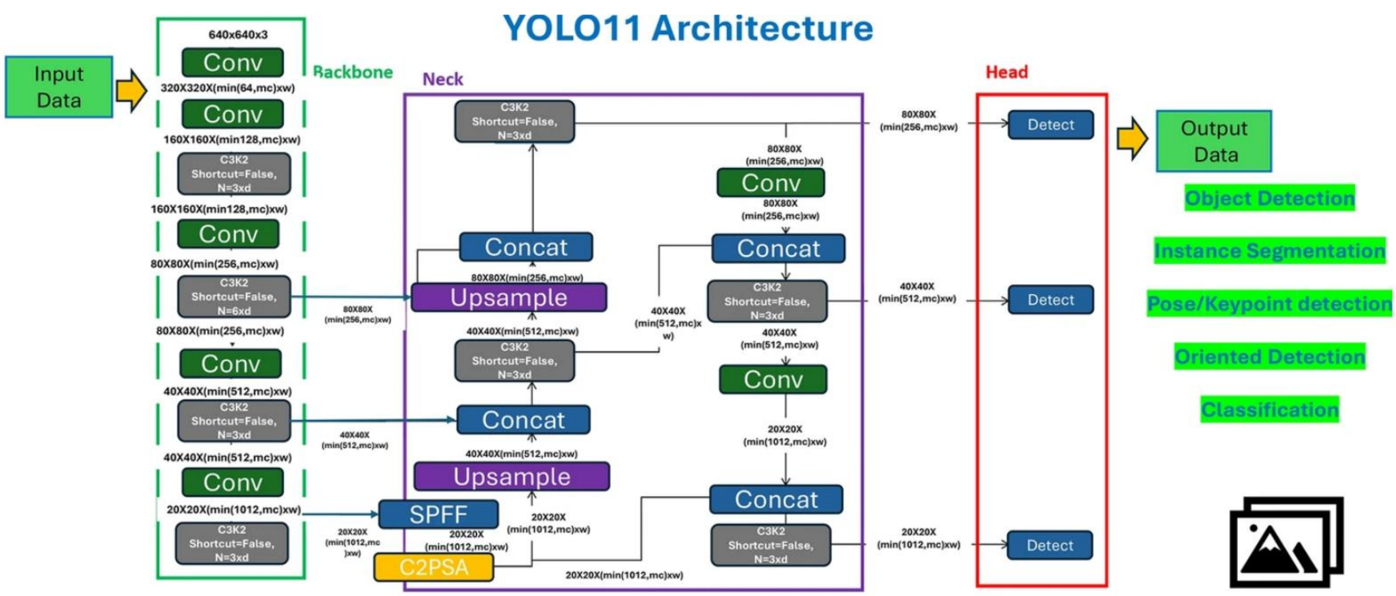
Firstly, Manpower is being used for the segregation of fruits to ensure the quality of fruits, but it’s a time-consuming procedure. Secondly, the non-availability of labor is the main impact on the segregation of fruits. If the labor force is available, the former cannot pay them as per their demands. Nowadays, it is not easy to manage agriculture sustainably because the population is increasing day by day [3]. We can use robots instead of humans because they do not get tired [4]. The gardening industry is facing a growing labor shortage because decline in interest in the labor force. As a result, many fruits were not picked and spoiled in the fields. Because the farms usually relied on forced labor [5]. The Labor cost can be reduced by robotic harvesting to improve fruit quality assessment. Segregation of fruits is a very important task because rotten fruits can damage the fresh fruits if they are not segregated. Segregation of fruits by hand is a hectic and time-consuming procedure [6]. Therefore, it is necessary to produce a model that can **segregate** as well **classify** the fruits automatically without getting tired to save time and provide benefits to the farmers in the agricultural industry.

Deep learning models, especially CNNs, have significantly improved fruit recognition and harvesting in agriculture. CNNs offer higher accuracy and speed than traditional machine learning methods [7]. In recent years, deep learning has gained a lot of success in computer vision tasks. From experiments, it is clear that Deep learning techniques are good as compared to other traditional and non-traditional techniques [8]. Deep learning has demonstrated remarkable potential in addressing Skin Disease [9] by using CNNs, Fungal Disease [10], Security

ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)

surveillance [11], Autonomous parking, [12], and waste segregation [13].

In this study, we are proposing a Deep learning model (Yolov11) which not only **classifies** the fruits but also **segregates** them on a quality basis. The model consists of an IoT device and a Detection unit. An IoT device is a camera that can receive a picture of fruit as input data and forward it to the Detection Unit (YOLOv11). The detection unit consists of three main parts: Backbone is responsible for feature extraction from input, Neck takes the feature from Backbone and does further processing, and Head takes the processed feature maps from Neck and gives the outputs. The architecture of the YOLOv11 model, **Ranjan Sapkota et al**, is given below.



Related Work:

The advancement in technology and Computer vision has contributed to the detection and classification of fruits spontaneously. Fruit's accurate classification and segregation play a vital role in agriculture. More than 2000 varieties exist in the world [14]. Many studies have been applied to the detection and classification of fruits. The CNN model has been applied for the classification of vegetables, achieving an accuracy of 95.5% [15]. Similarly, fuzzy logic. Decision trees, MLPNeural, and

ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)

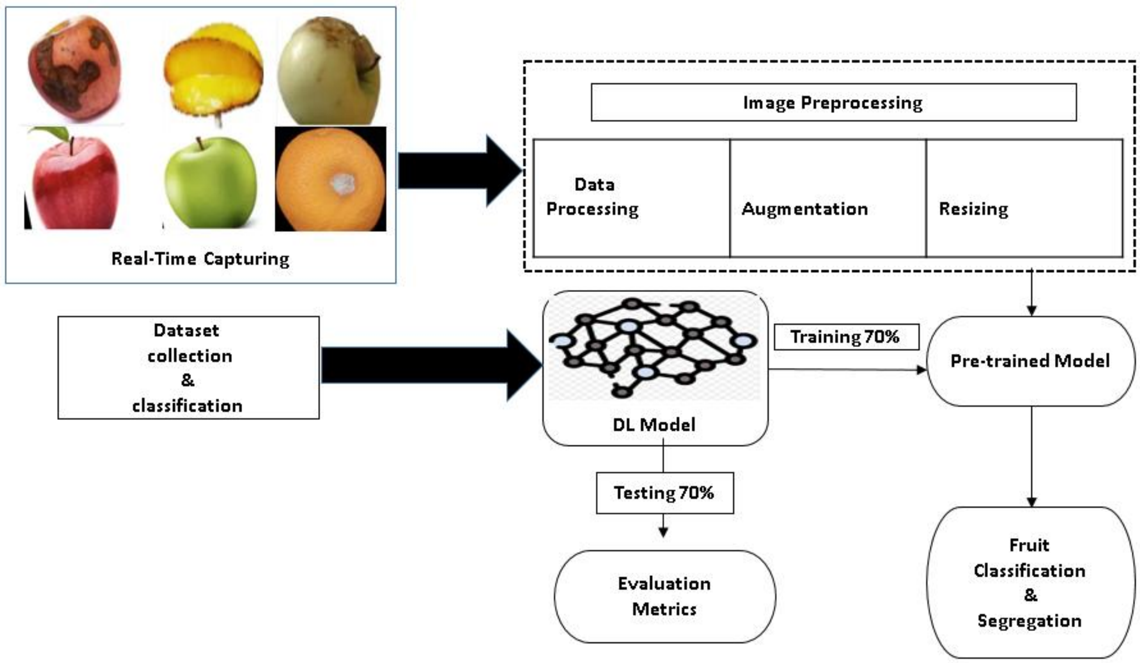
principal component analysis are used in citrus fruits for skin detection [16]. Joseph et al. proposed a CNN-based automatic model for classification, achieving an accuracy of 95% [17]. Ponce et al. used multiple CNN models, with Inspection-ResNetV2 to classify Olives, achieving 95.91% accuracy [17]. Seng et al. utilized KNN in a custom-built dataset of 50 pictures, achieving 90% accuracy [18]. Shiv and Anand developed a Gaussian Naïve-based classifier to classify varieties of apples and citrus fruits [19], achieving 70% testing accuracy. Several studies have extended to disease detection. Abayomi-Alli et al. found the cassava leaf disease by using MobileNetv2 and gained an accuracy of 97.7% [20]. Almadhor et al. used CCR-NN (custom convolutional recurrent neural network) to detect the cassava mosaic viruses [21]. But these models are not appropriate for real-time object recognition. Moreover, few studies used Deep learning models with mobile applications for object recognition. Deep learning models, especially the YOLO series, are best for real-time object detection. The Yolo series model can detect and classify objects in one step with the best accuracy.

Construction and Working of Proposed Model:

The proposed model consists of an input unit and, detection unit. The input unit consists of an IoT device (camera) that takes the picture and forwards it detection unit. The detection unit processes the images and classifies as well as segregates images in just one

ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)

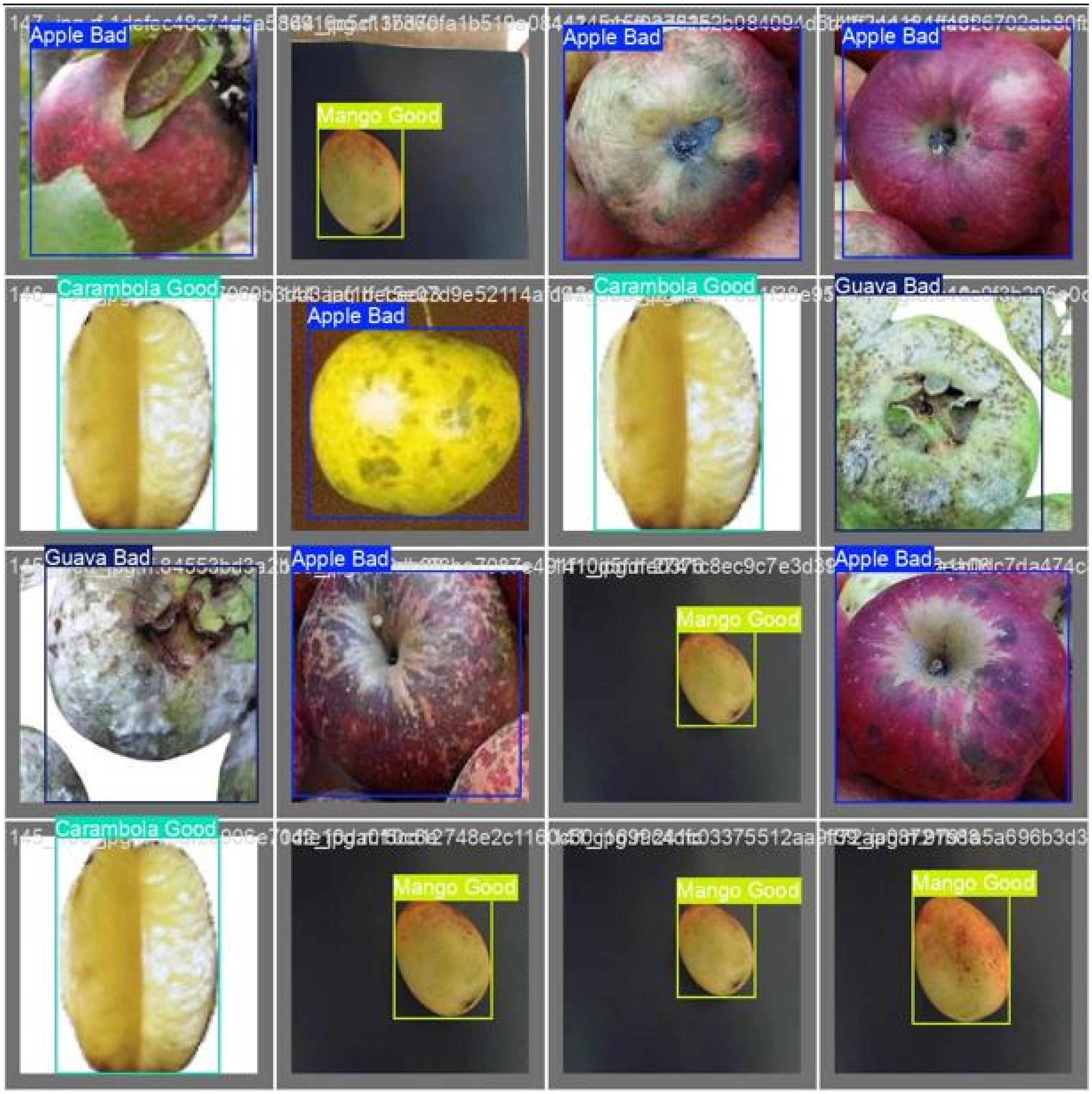
step.



Block Diagram of Proposed System

The picture below shows the segregated fruits.

JOURNAL OF EMERGING TECHNOLOGY AND DIGITAL TRANSFORMATION
ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)



JOURNAL OF EMERGING TECHNOLOGY AND DIGITAL TRANSFORMATION
ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)

The following figure shows the classified fruits with quality grading.

JOURNAL OF EMERGING TECHNOLOGY AND DIGITAL TRANSFORMATION
ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)

The picture below shows the classified as well segregated fruits.

JOURNAL OF EMERGING TECHNOLOGY AND DIGITAL TRANSFORMATION
ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)

Methodology:

This study includes numerous key phases: dataset preparation, model selection, training, evaluation, and deployment. The complete workflow is planned to automate fruit classification and segregation using deep learning-based object detection models.

1. **Dataset Collection and Annotation**

The dataset (**fruit vision classification**) was sourced from **Roboflow**, a platform for managing computer vision datasets. The dataset contains multiple classes of fruits (annotated images in Yolo format). Datasets include 77% images for training and 23% images for the validation test.

The dataset was augmented using Roboflow's built-in tools (e.g., rotation, flipping, blur, noise), which enhance model robustness against environmental variations.

2. **Model Selection**

The Yolov11 model is chosen in this study because of its real-time object detection capability and high accuracy. The architecture of Yolov11 allows for to extraction of features efficiently.

The Model was trained in Google Colab.

For simulation, the model was trained using:

```
!yolo task=detect mode=train model=yolov9s.pt data=/content/drive/MyDrive/Fruits/fruit-vision-classification-2/data.yaml epochs=100 imgsz=224 plots=True
```

Performance Metrics:

Metric	Formula	Explanation
Precision	$\frac{tp}{tp + Fp}$	Measure the correctness of the model
Recall	$\frac{tp}{tp + Fn}$	Handle the classification problems of the classes
Accuracy	$\frac{tp + tn}{tp + tn + Fp + Fn}$	Measure the correctness of a classification model.

JOURNAL OF EMERGING TECHNOLOGY AND DIGITAL TRANSFORMATION
ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)

F1-Score	$2 * \frac{Precision * Recall}{Precision + Recall}$	It is the harmonic mean between Precision and Recall.

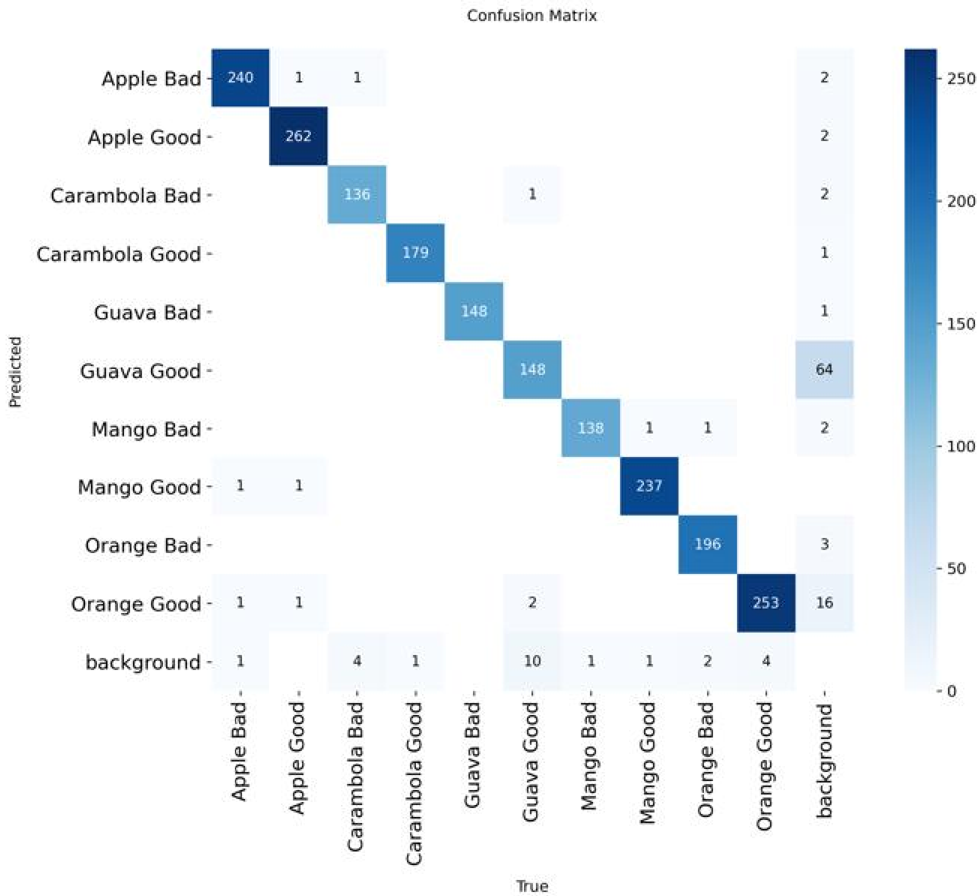
Evaluation of Performance Metrics (Results of Simulation):

Metric performance is used to measure the accuracy and efficiency of deep learning models. Main metrics comprise precision, recall, F1-score, and mAP, which display how well the model identifies and classifies objects. High precision guarantees correct predictions, while high recall checks minimal missed findings.

Confusion Metrix:

It measures the performance of the classification model. It is the ratio of the number of predictions predicted as correct to the total number of predictions. The metric contains True Positive, True Negative, and False Negative values.

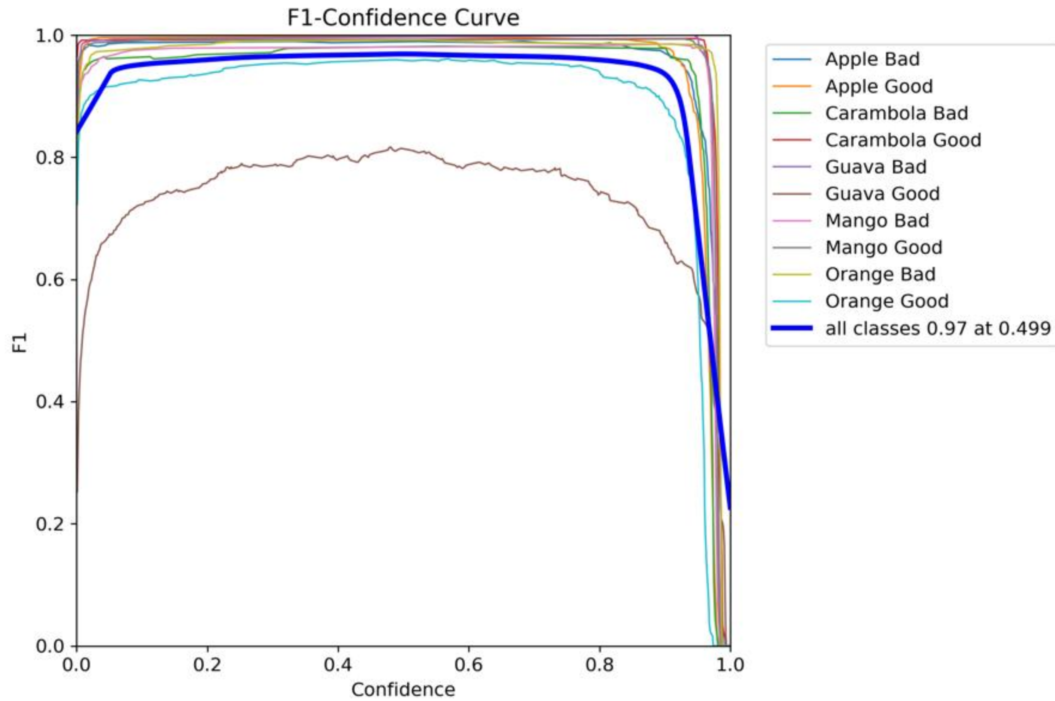
JOURNAL OF EMERGING TECHNOLOGY AND DIGITAL TRANSFORMATION
ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)



F-1 Confidence curve

The F-1 score involves both precision and recall to check the accuracy, especially when the data is imbalanced.

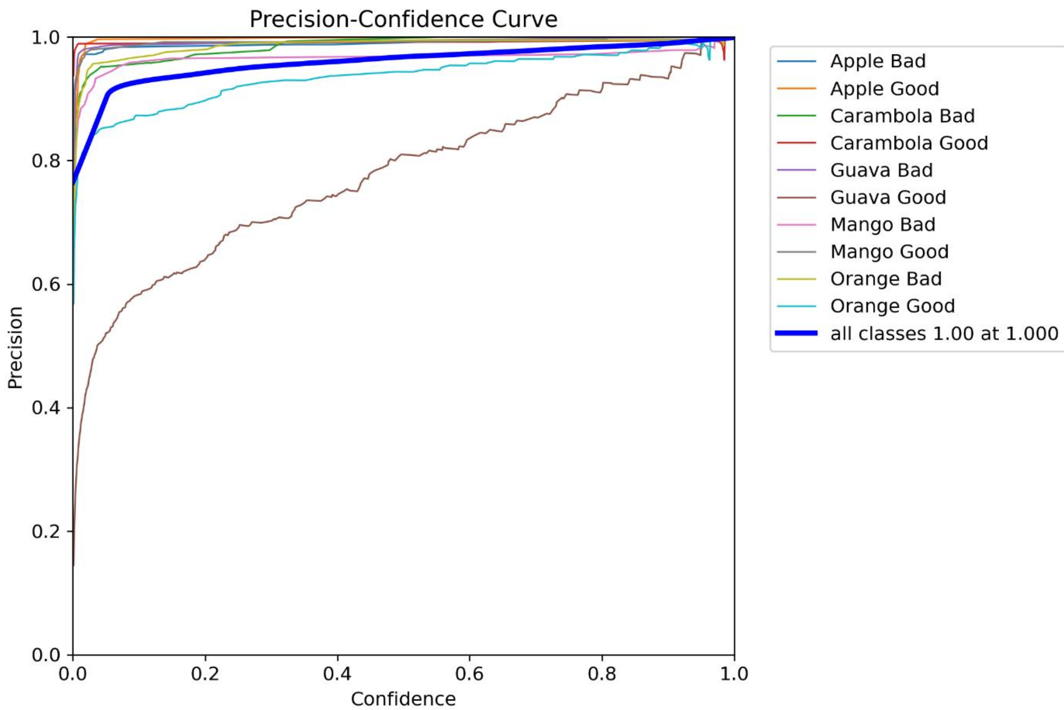
JOURNAL OF EMERGING TECHNOLOGY AND DIGITAL TRANSFORMATION
ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)



Precision:

It measures how the model returns the most relevant results.

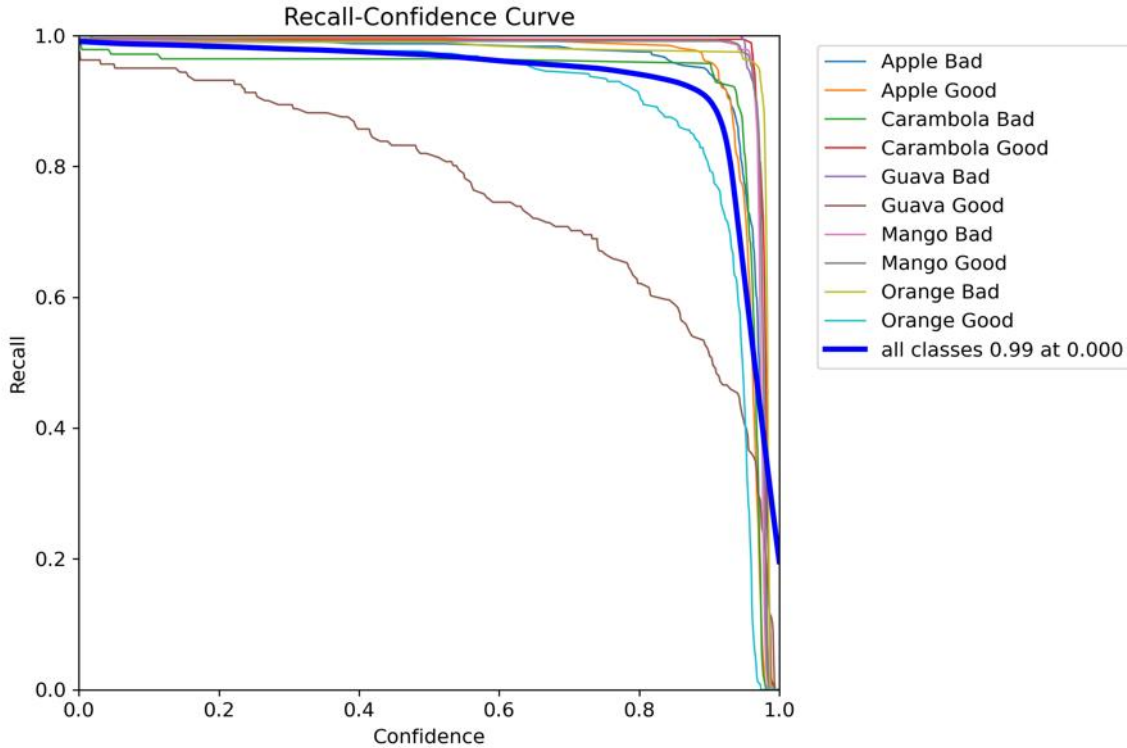
ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)



Recall:

It tells how successfully the model captures the actual positives.

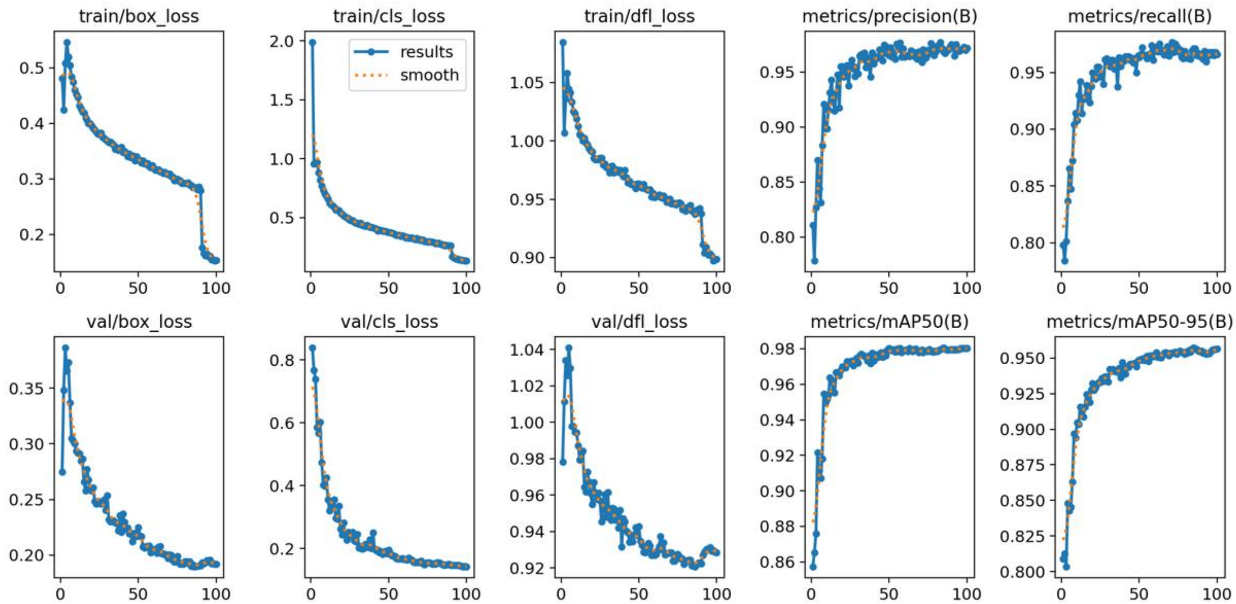
JOURNAL OF EMERGING TECHNOLOGY AND DIGITAL TRANSFORMATION
ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)



Results:

The graphs in the results tell about the performance of the model.

JOURNAL OF EMERGING TECHNOLOGY AND DIGITAL TRANSFORMATION
ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)



YOLO Models' results on different datasets

Model	Percentage Precision	Percentage Recall	Percentage mAP50	Percentage F-1 Score	Percentage Validation Accuracy
YOLOv5s	89.8	88.3	92.7	7.02	
YOLOv7s	89.6	88.4	92.2	36.48	
Yolov7s + CBAM + GSConv + WIOU + CARAFE	90.8	86.4	91.9	26.41	
YOLOv8s	89.8	86.1	93.0	11.12	
YOLOv9c	91.1	87.1	93.8	50.70	
SRN-Yolo *(Gao et al., 2024)*	92.4	87.4	94.4	53.27	
Yolov8-SIM *(Randar et al., 2024)*	90.8	87.3	93.6	11.32	
Yolo-SAG *(Chen et al., 2024)*	90.3	88.1	93.6	11.35	
Yolo-MIF *(Wan et al., 2024)*	90.1	88.	93.5	11.13	
DNE-YOLO	90.7	88.9	94.3	10.46	
YOLOv5	90.81	88.043	95.24		

JOURNAL OF EMERGING TECHNOLOGY AND DIGITAL TRANSFORMATION
ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)

Model	Percentage Precision	Percentage Recall	Percentage mAP50	Percentage F-1 Score	Percentage Validation Accuracy
YOLOv6	88.92	92.13	96.11		
YOLOv7 (Nur-E-Aznin Mimma et al.2022)	93	89			96.1
YOLO V8 (Fuqin Deng et al.2025)	88.6	93.3	93.4		
YCCB-YOLO ([22])	91.79	92.75	97.32		
YOLOv11	**Average 96.96**	**Average 97.12**	**Average 98.15**	**Average 98.15**	**Average 97.19**

ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)

Conclusion

Fruit classification and segregation are critical processes in the agricultural as well food Industry. The classification and segregation ensure the quality, the health, and the waste. Traditional methods are not suitable due to rising labor costs and a shortage of the workforce. They are time-consuming methods. As the population increases, the mandate of automated solutions is becoming more urgent. This study provides an authentic and efficient solution for the real-time fruit detection, classification, and segregation of fruits based on quality using a deep learning model. By integrating an IoT device with an advanced object detection unit, the model improves the speed and accuracy of fruit sorting while reducing human efforts. The model architecture allows impressive feature extraction and processing. The Proposed model provides a promising alternative to traditional fruit classification and segregation. It not only ensures the quality of fruits but also provides benefits to the farmers by reducing the operational costs and post-harvest losses. With further optimization in this field of search, smart solutions can play a transformative role in achieving sustainable and efficient food supply chains.

References:

[1] J. L. Slavin and B. Lloyd, “Health Benefits of Fruits and Vegetables,” *Adv. Nutr.*, vol. 3, no. 4, pp. 506–516, 2012, doi: https://doi.org/10.3945/an.112.002154.

[2] S. S. Reka, A. Bagelikar, P. Venugopal, V. Ravi, and H. Devarajan, “Deep Learning-Based Classification of Rotten Fruits and Identification of Shelf Life.,” *Comput. Mater. Contin.*, vol. 78, no. 1, 2024.

[3] A. Gamage *et al.*, “Role of organic farming for achieving sustainability in agriculture,” *Farming Syst.*, vol. 1, no. 1, p. 100005, 2023, doi: https://doi.org/10.1016/j.farsys.2023.100005.

[4] L. Peternel, N. Tsagarakis, D. Caldwell, and A. Ajoudani, “Robot adaptation to human physical fatigue in human–robot co-manipulation,” *Auton. Robots*, vol. 42, pp. 1–11, Jun. 2018, doi: 10.1007/s10514-017-9678-1.

ONLINE ISSN
3006-9726
PRINT ISSN
3006-9718
VOLUME . 4 ISSUE . 2 (2025)

[5] H. Zhou, X. Wang, W. Au, H. Kang, and C. Chen, "Intelligent robots for fruit harvesting: Recent developments and future challenges," *Precis. Agric.*, vol. 23, no. 5, pp. 1856–1907, 2022.

[6] S. S. S. Palakodati, V. R. R. Chirra, D. Yakobu, and S. Bulla, "Fresh and Rotten Fruits Classification Using CNN and Transfer Learning.," *Rev. d'Intelligence Artif.*, vol. 34, no. 5, pp. 617–622, 2020.

[7] F. Xiao, H. Wang, Y. Xu, and R. Zhang, "Fruit detection and recognition based on deep learning for automatic harvesting: An overview and review," *Agronomy*, vol. 13, no. 6, p. 1625, 2023.

[8] L. Liang, L. Zhu, W. Shang, D. Feng, and Z. Xiao, "Express supervision system based on NodeJS and MongoDB," in *2017 IEEE/ACIS 16th International Conference on Computer and Information Science (ICIS)*, IEEE, 2017, pp. 607–612.

[9] Gulzar Ahmad *et al.*, "Mobile Application for Skin Disease Classification Using CNN with User Privacy," *J. Comput. Biomed. Informatics*, no. SE-Articles, Apr. 2024, [Online]. Available: https://jcbi.org/index.php/Main/article/view/432

[10] T. Alyas, K. Alissa, A. S. Mohammad, S. Asif, T. Faiz, and G. Ahmed, "Innovative Fungal Disease Diagnosis System Using Convolutional Neural Network," 2022. doi: 10.32604/cmc.2022.031376.

[11] Q. Abbas, G. Ahmad, T. Alyas, T. Alghamdi, Y. Alsaawy, and A. Alzahrani, "Revolutionizing Urban Mobility: IoT-Enhanced Autonomous Parking Solutions with Transfer Learning for Smart Cities," 2023. doi: 10.3390/s23218753.

[12] kashif iqbal Shah, S. Abbas, M. Khan, A. Athar, M. Saleem Khan, and G. Ahmad, "Autonomous Parking-Lots Detection with Multi-Sensor Data Fusion Using Machine Deep Learning Techniques," *C. -Tech Sci. Press.*, vol. 66, pp. 1595–1612, Nov. 2020, doi: 10.32604/cmc.2020.013231.

[13] J. Vargas, G. Ahmad, B. Sheikh, Hameed, R. Bokhari, and T. Tajammal, "Smart Cities'

Automatic Image-Based Waste Segregation through an Intelligent Agent Using CNN," Mar. 2025.

[14] G. S. Khush, *IR varieties and their impact*. Int. Rice Res. Inst., 2005.

[15] A. Nasiri, A. Taheri-Garavand, and Y.-D. Zhang, "Image-based deep learning automated sorting of date fruit," *Postharvest Biol. Technol.*, vol. 153, pp. 133–141, 2019.

[16] F. López-García, G. Andreu-García, J. Blasco, N. Aleixos, and J.-M. Valiente, "Automatic detection of skin defects in citrus fruits using a multivariate image analysis approach," *Comput. Electron. Agric.*, vol. 71, no. 2, pp. 189–197, 2010, doi: https://doi.org/10.1016/j.compag.2010.02.001.

[17] J. M. Ponce, A. Aquino, and J. M. Andújar, "Olive-Fruit Variety Classification by Means of Image Processing and Convolutional Neural Networks," *IEEE Access*, vol. 7, pp. 147629–147641, 2019, doi: 10.1109/ACCESS.2019.2947160.

[18] W. C. Seng and S. H. Mirisaee, "A new method for fruits recognition system," in *2009 International Conference on Electrical Engineering and Informatics*, 2009, pp. 130–134. doi: 10.1109/ICEEI.2009.5254804.

[19] S. R. Dubey and A. S. Jalal, "Species and variety detection of fruits and vegetables from images," *Int. J. Appl. Pattern Recognit.*, vol. 1, no. 1, pp. 108–126, 2013.

[20] O. O. Abayomi-Alli, R. Damaševičius, S. Misra, and R. Maskeliūnas, "Cassava disease recognition from low-quality images using enhanced data augmentation model and deep learning," *Expert Syst.*, vol. 38, no. 7, p. e12746, 2021.

[21] A. Almadhor, H. T. Rauf, M. I. U. Lali, R. Damaševičius, B. Alouffi, and A. Alharbi, "AI-driven framework for recognition of guava plant diseases through machine learning from DSLR camera sensor based high resolution imagery," *Sensors*, vol. 21, no. 11, p. 3830, 2021.

[22] G. Ang *et al.*, "Fruits hidden by

green: an improved YOLOV8n for detection of young citrus in lush citrus trees," *Front. Plant Sci.*, vol. 15, p. 1375118., Apr. 2024, doi: 10.3389/fpls.2024.1375118.