A Project report on

Fruit Ripeness Detection using OpenCV

A Dissertation submitted to JNTU Hyderabad in partial fulfillment of the academic requirements for the award of the degree.

Bachelor of Technology

in

Computer Science and Engineering (DATA SCIENCE)

Submitted by

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CERTIFICATE

This is to certify that the Mini Project I report entitled **"Fruit Ripeness Detection using OpenCV"** being submitted by **Wajeeha Samreen (21H51A6746)** in partial fulfillment forthe award of **Bachelor of Technology in Computer Science and Engineering (Data Science)** is a record of bonafide work carried out his/her under my guidanceand supervision.

The results embody in this project report have not been submitted to any other University or Institute for the award of any Degree.

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ABSTRACT

The agricultural industry faces challenges in optimizing fruit harvesting processes, where accurate and timely ripeness detection is crucial for ensuring product quality and reducing waste. This study proposes a novel approach to fruit ripeness detection using OpenCV, a popular computer vision library. The methodology involves the development of a robust algorithm that leverages image processing techniques to analyze fruit images and determine their ripeness status. The process begins with the acquisition of high-resolution images of fruits in various stages of ripeness. These images serve as the input data for the proposed algorithm, which employs color-based segmentation techniques to isolate the fruit from the background. Subsequently, feature extraction methods are applied to capture key characteristics associated with ripeness, such as color intensity, texture, and shape. OpenCV's machine learning capabilities are then utilized to train a model capable of classifying fruits into distinct ripeness categories. The model is trained on a labeled dataset, incorporating images of fruits at different ripeness stages. The trained model is subsequently applied to new images, providing real-time ripeness assessments. To enhance the system's adaptability and accuracy, the algorithm incorporates dynamic thresholding techniques to account for variations in lighting conditions and fruit types. Additionally, the implementation includes a user-friendly interface for easy integration into existing agricultural workflows. The proposed approach demonstrates promising results in terms of accuracy and efficiency, showcasing its potential to revolutionize fruit harvesting practices. By automating the ripeness detection process, farmers and agricultural professionals can make more informed decisions about the optimal timing for harvesting, leading to improved yield quality and reduced post-harvest losses.

LIST OF FIGURES

LIST OF ACRONYMS

S.NO	ACRONYM NAME	FULL FROM
1	OpenCV	Open-Source Computer Vision Library
2	RGB	Red Green Blue
3	HSV	Hue saturation value
4	GSM	Global system for mobile communications
5	CNNs	Convolutional Neural Networks
6	ML	Machine Learning
7	IoT	Internet of things
8	RAM	Random excess memory
9	CMYK	Cyan, Magenta, Yellow, Key
10	ROI	Reign of interest

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CHAPTER 1

1. INTRODUCTION

1.1 Motivation

Fruit ripeness detection is a crucial task in the agricultural and food industry. The ability to accurately determine the ripeness of fruits can impact various stages of the supply chain, from harvesting to distribution and consumption. One effective way to perform fruit ripeness detection is by leveraging computer vision techniques, and OpenCV (Open-Source Computer Vision Library) is a powerful tool for this purpose.

The flexibility of OpenCV facilitates the integration of additional machine learning components, allowing for continuous improvement and adaptation to diverse fruit types and environmental conditions. This adaptability is particularly valuable in addressing the variability in fruit appearance due to factors such as species, cultivar, and ripening conditions. As technology continues to advance, fruit ripeness detection using OpenCV holds the potential to enhance productivity, reduce waste, ensure the delivery of high-quality produce to consumers. The development and refinement of such systems contribute to the broader field of precision agriculture and smart food processing, paving the way for more sustainable and efficient practices in the agri-food sector. The initiation of fruit ripeness detection begins with the acquisition of a diverse and representative dataset. This dataset comprises images capturing fruits at different ripeness stages under various environmental conditions. The subsequent phase involves meticulous image preprocessing, wherein techniques like resizing, cropping, and normalization are applied to enhance the pertinent features essential for ripeness analysis. A pivotal step in this process is the conversion of images into an appropriate color space, with the HSV color space often proving to be effective due to its ability to encapsulate color information comprehensively. Segmentation techniques, including thresholding and contour detection provided by OpenCV, are then employed to isolate the fruits from the background, facilitating focused analysis. Following segmentation, feature extraction takes center stage. Features indicative of ripeness, such as color intensity, texture, and shape, are extracted from the segmented fruits. These features serve as the input for the subsequent machine learning classifier, where OpenCV's versatile tools support the training of classifiers ranging from Support Vector Machines to Random Forests and Convolutional Neural Networks.

1.2 Problem Definition

Food waste causes numerous issues for the agriculture sector, such as picking crops before they are ready. So, this may result in food waste and financial loss for farmers. Our project, fruit ripeness detection, aims to address this issue. The basis for this project is OpenCV. It will function by utilizing computer vision techniques and algorithms. Therefore, before fruit is picked, this project helps to determine if it is ripened or not. In order to prevent food waste and to ensure that farmers do not suffer losses.

1.3 Objective of Project

The Fruit Ripeness Detection System revolutionizes agricultural practices by automating and accurately assessing fruit ripeness using OpenCV and computer vision. Its image preprocessing, color space conversion, and adaptable machine learning components ensure accuracy across various fruits and environmental conditions. A Beyond efficiency gains, this system significantly reduces food waste, aligning with sustainability goals. And its dynamic, data-driven approach fosters continuous improvement, aiding precision agriculture by enabling real-time decision-making for optimized resource allocation and harvest timing. This not only enhances fruit quality but also boosts market competitiveness and profitability. In essence, this transformative technology redefines fruit ripeness assessment, merging computer vision, machine learning, and sustainability to create a more efficient, eco-friendly, and economically viable future for agriculture.

1.4 Overview of Color Based – Approach

The color-based approach for fruit ripeness detection, employing computer vision via OpenCV, relies on a step-by-step process:

1. **Image Capture:** Quality images of fruits are taken to ensure accurate color analysis.
2. **Color Space Conversion:** RGB images are converted to the HSV color space, emphasizing hue for better color separation.
3. **Fruit Region Isolation:** Analyzing the hue component, specific fruit regions are identified using thresholding techniques.
4. **Thresholding Methods:** Criteria are set to classify pixels as fruit or non-fruit, adapting to varying lighting conditions.

5. **Region Refinement:** Boundaries of identified fruit regions are refined for precise representation.

6**. Color Histogram Analysis:** Histograms of extracted regions depict color distribution, revealing ripe characteristics.

7**. Ripeness Classification:** Using color data, fruits are categorized based on pre-set thresholds or machine learning models trained on labeled datasets.

8. **Visual Output:** Results overlay ripeness classifications on original fruit images, illustrating ripeness levels within the fruit.

CHAPTER 2
2. BACKGROUND WORK

2.1 Existing Systems

2.1.1 Smart Detection System for Fruit Ripeness

1. The proposed system will provide a much better and convenient way for farmers to get the maturity of fruit.
2. This includes a series of steps from capturing the image of fruit to identify whether the fruit is fully ripened or moderately ripe through IOT device microcontroller by implementing in Raspberry Pi device.
3. The camera module is interfaced with Raspberry pi and the captured images are examined by various steps like preprocessing and segmentation.
4. The status of the fruit has been sent by GSM module through SMS and displaying the status on the monitor display of the owner of the system. This is a smart way of analyzing the fruit is ripe or unripe to yield and helps the farmers to understand the potential of agriculture by installing smart technologies to increase competitions and sustainability in their production.
5. With the increasing growth of world population, the agricultural industry is demanding technological solutions focused on growth of food production and farming to enhance the farm yield. Nowadays, technology is constantly improving to solve human problems more easily.
6. The manual experimentation and assessment through trial-and-error etc are no longer practicable. The intelligent system can be established for fruits that can permit the quality analysis.
7. This will further help for the automatic fruit harvesting system using robotic arm.

2.1.2 Fruit Ripeness Detection using Machine Learning

1. In this we introduce ripeness of fruit using a new, high-quality, dataset of images containing all type fruits.
2. Fruit ripeness detection using machine learning typically involves training a model on a dataset of images, where each image is labeled with the corresponding ripeness stage.

3. Convolutional Neural Networks (CNNs) are commonly used for image classification.
4. involves collecting a labeled dataset of fruit images, preprocessing the data for consistency
5. It shows whether the fruit is ripe or unripe by this means of classification. One of the most important sectors in any country is the agricultural sector. However, in some countries, farmers and fishermen have limited technology compared to other developed countries.
6. One of the effects of limited technology is the low quality of crops, fruits, and vegetables. This is because the quality of the products is only assessed depending on external factors like appearance, shape, color, and texture, which can be prone to human error.
7. Determining the quality and ripeness level of fruit requires consistency, which can be hard and tedious for humans when it becomes repetitive work.
8. This paper aims to present various methods and approaches on how ripe fruit detection and classification can be made easier and more convenient using machine learning and machine vision algorithms. Furthermore, this study presents Systems that can be utilized in pre and post-harvest analysis.
9. This paper aims to provide solutions using computer applications to help farmers have lesser manual labor yet more accurate data and results in the evaluation of crops.

2.2 Disadvantages of Existing system

1. **Limited Generalization:** ML models struggle to generalize across diverse fruit varieties due to differences in size, shape, and color.
2. **Dependency on Training Data:** ML model accuracy relies heavily on the quality and diversity of training data, affecting real-world applicability.
3. **Environmental Variability:** Changes in lighting, weather, and environmental factors pose challenges for consistent and accurate ripeness detection.
4. **Real-time Processing Constraints:** ML models may be resource-intensive, making real-time processing challenging, especially on IoT devices with limited computational power.
5. **Security and Privacy Concerns:** Transmitting sensitive ripeness data over networks raises concerns about data security and privacy on IoT devices.

2.3 Proposed System

The new system we are proposing is like a smart detective for fruits, making sure they are at the right level of ripeness. Our system uses a powerful tool called OpenCV to look at pictures of fruits and figure out if they're ready to be eaten. OpenCV helps us do this by turning the pictures into a form it can understand better. the system gets to work, separating the fruits from the background and picking out important details like color and shape. The system can be helpful in many areas, like helping farmers know when to harvest their crops or making sure the fruits you see at the store are just right for you to take home.

1. It is a basic computer vision script for fruit ripeness detection using the OpenCV library in Python.
2. It captures frames from a camera feed, converts them to the HSV color space, and defines color ranges to create masks for identifying ripe and unripe regions based on color characteristics.
3. The algorithm used in this is based on basic computer vision techniques, specifically color thresholding and pixel counting
4. The script then counts the number of pixels in each mask and calculates the percentage of ripe and unripe pixels relative to the total number of pixels in the image.
5. The results are displayed on the frame in real-time.

CHAPTER 3

3. ANALYSIS

3.1 Software and Hardware Requirements

3.1.1 Software Requirements:

- Programming Language: python
- OpenCV

3.1.2 Hardware Requirements:

- Computer or server
- Laptop with Camera
- Memory (RAM): RAM (4GB -8GB)

3.2 Algorithm

- **Canny Edge Detector:**

The Canny Edge Detector, developed by John F. Canny in 1986, is a multi-stage algorithm widely used in computer vision and image processing. It starts with Gaussian smoothing to reduce noise in the image. Next, the gradients are calculated to determine the intensity change direction. Non-maximum suppression is applied to thin out the edges, retaining only local maxima. Finally, edges are tracked using hysteresis, where weak edges are connected to strong ones. The algorithm is praised for its ability to detect meaningful edges while minimizing false positives, making it a cornerstone in edge detection applications.

- **Contour Tracing:**

Contour tracing involves navigating through an image to identify connected pixels forming the boundaries of objects. This process is commonly implemented using algorithms like the Moore-Neighbor Tracing or the Freeman Chain Code. Once contours are established, they can be utilized for shape analysis, object recognition, and tracking. Contour information is fundamental in computer vision tasks where understanding object shapes and structures is crucial.

- **Color Space Conversion:**

  Color space conversion is essential for managing and interpreting color information in images. Different color spaces offer unique advantages for specific tasks. For example, the HSV color space separates hue, saturation, and value, making it easier to manipulate colors independently. RGB is commonly used for display purposes, while CMYK is prevalent in printing. Color space conversion enables adjustments for color correction, segmentation, and various image processing tasks, accommodating diverse requirements in different applications.

- **Color Thresholding Algorithms:**

  Color thresholding involves setting criteria to classify pixels based on color values. In a typical RGB image, each pixel has three color channels: red, green, and blue. Thresholds are defined for each channel, and pixels falling within the specified ranges are considered. This method is powerful in scenarios where specific colors need to be isolated or emphasized, such as in medical image analysis, where particular tissue types might be distinguished based on color. Effective color thresholding algorithms contribute to accurate image segmentation and analysis.

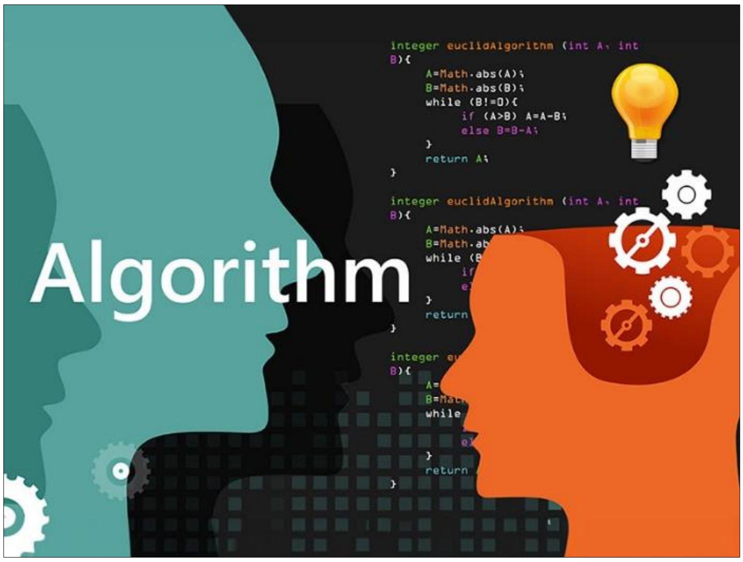


Fig 3.2.1 Algorithm

CHAPTER 4
4. DESIGN

4.1 Architecture of Fruit Ripeness Detection

In a fruit ripeness detection system, the process typically begins with Initialization, where the system is set up and calibrated. Image Acquisition involves capturing pictures of the fruit using cameras or other imaging devices. Pre-processing entails cleaning and enhancing the images to improve the accuracy of subsequent analysis. Color Analysis focuses on examining the color characteristics of the fruit, as ripeness often correlates with changes in color. Pixel Counting involves quantifying the number of pixels associated with specific color ranges or features relevant to ripeness. Percentage Calculation then determines the proportion of ripe areas based on the pixel count.

Finally, Ripeness Detection involves interpreting the calculated percentages to classify the fruit as either ripe or unripe. This comprehensive approach integrates image processing techniques and color analysis to automate the assessment of fruit ripeness, offering a valuable tool in quality control and agricultural applications.

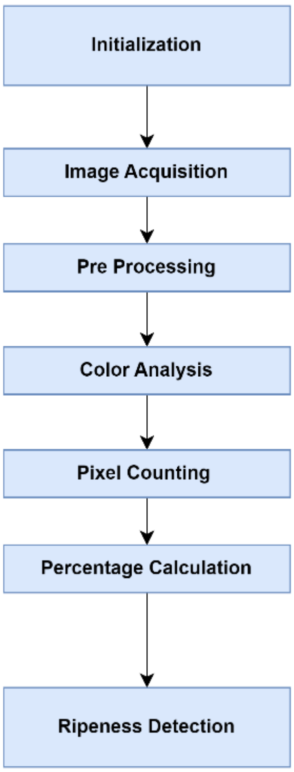


Fig 4.1 System Architecture

4.2 System Module

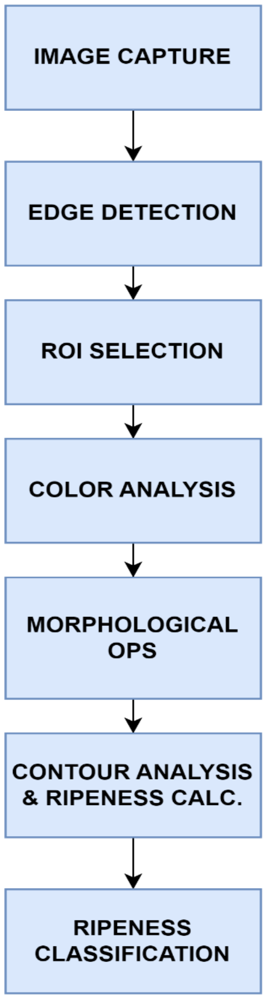


Fig 4.2 Module Diagram

4.2.1 Explanation of Module

The fruit ripeness detection process involves key functions: Image Captures a high-quality image, Edge Detection enhances feature visibility, ROI Selection isolates the fruit area for focused analysis, Color Analysis examines color characteristics, Morphological Operations refine shape, and Contour Analysis calculates ripeness. These functions collectively form a comprehensive pipeline for automated and accurate fruit ripeness assessment.

4.3 Step by step process of Implementation:

1. **Image Acquisition:**

   Image acquisition and preprocessing play crucial roles in the success of a fruit ripeness detection system based on color analysis. These steps ensure that the input images are of high quality, free from noise, and suitable for subsequent analysis. Here's an overview of image acquisition and preprocessing in the context of a color-based approach using OpenCV

1. **Camera Setup:**

   Utilize cameras or imaging devices capable of capturing high-resolution images. Consider factors such as focal length, lighting conditions, and camera angle to ensure accurate color representation.

2. **Consistent Lighting:**

   Ensure consistent and uniform lighting across images to minimize variations that may affect color analysis. Avoid harsh shadows or overly bright conditions that can distort color information.

3. **Calibration:**

   Calibrate the imaging system if necessary to correct for color distortions or variations. This step may involve using color calibration charts to standardize color representation across images.

4. **Multiple Angles and Views:**

   Capture images of fruits from multiple angles and views to ensure comprehensive coverage. This helps account for variations in color appearance due to surface orientation and shape.

5. **Resizing:**

   Resize images to a standard resolution for consistency in analysis. This step helps reduce computational load and ensures that the system is not overly sensitive to variations in image dimensions.

6. **Noise Reduction:**

   Apply noise reduction techniques to improve the overall quality of the images. This may involve using filters like Gaussian or median filters to smooth out irregularities caused by sensor noise or other artifacts.

7. **Color Space Conversion:**

   Convert the images from the RGB color space to a space more suitable for color analysis, such as the HSV (Hue, Saturation, Value) color space. This conversion helps separate color information into more meaningful components.

CHAPTER 5

5. IMPLEMENTATION AND RESULT

5.1 Process of Implementation

5.1.1 Image Capture and Edge Detection

```
camera = cv2.VideoCapture(0)
return_value, image = camera.read()
cv2.imwrite(i + '.jpeg', image)
del(camera)
frame = image
edge_img = deepcopy(image)
edged = cv2.Canny(edge_img, 50, 100)
edged = cv2.dilate(edged, None, iterations=1)
edged = cv2.erode(edged, None, iterations=1)
cnts, h = cv2.findContours(edged.copy(), cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)
max_cont = max(cnts, key=cv2.contourArea)
x, y, w, h = cv2.boundingRect(max_cont)
```

- The code captures an image from the camera, saves it, and performs edge detection using the Canny edge detector.
- It finds the largest contour in the edge-detected image and extracts the bounding rectangle.

5.1.2 Red color Masking and contour Detection

```
hsv = cv2.cvtColor(frame, cv2.COLOR_BGR2HSV)
lower_red = np.array([0, 50, 50])
upper_red = np.array([10, 255, 255])
redmask1 = cv2.inRange(hsv, lower_red, upper_red)
lower_red = np.array([170, 50, 50])
upper_red = np.array([180, 255, 255])
redmask2 = cv2.inRange(hsv, lower_red, upper_red)
redmask = redmask1 + redmask2
maskOpen = cv2.morphologyEx(redmask, cv2.MORPH_OPEN, kernelOpen)
maskClose = cv2.morphologyEx(maskOpen, cv2.MORPH_CLOSE, kernelClose)
maskFinal = maskClose
cv2.imshow('Red_Mask:', maskFinal)
cnt_r, _ = cv2.findContours(maskFinal, cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)
cnt_r_area = sum(cv2.contourArea(c) for c in cnt_r)
```

- Converts the image to the HSV color space for better color representation.
- Defines HSV ranges for the red color and creates binary masks.
- Combines masks and applies morphological operations (opening and closing) to reduce noise
- Finds contours in the final red mask and calculates the total area of redness.

5.1.3 Green and Yellow Color detection

```
lower_green = np.array([50, 50, 50])
upper_green = np.array([70, 255, 255])
greenmask = cv2.inRange(hsv, lower_green, upper_green)
cv2.imshow('Green_Mask:', greenmask)
cnt_g = cv2.countNonZero(greenmask)
print("Greenness ", cnt_g)
lower_yellow = np.array([20, 50, 50])
upper_yellow = np.array([50, 255, 255])
yellowmask = cv2.inRange(hsv, lower_yellow, upper_yellow)
cv2.imshow('Yellow_Mask:', yellowmask)
cnt_y = cv2.countNonZero(yellowmask)
print("Yellowness ", cnt_y)
```

- Defines HSV ranges for green and yellow colors and creates binary masks.
- Counts the number of non-zero pixels in the green and yellow masks.

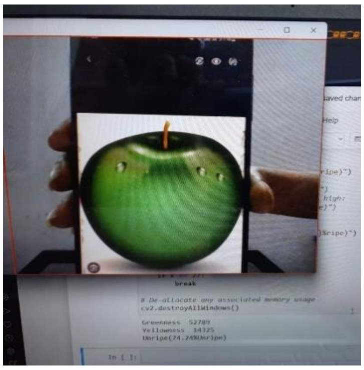
5.1.4 Ripeness Calculation and Classification

```
tot_area = cnt_r_area + cnt_y + cnt_g
rperc = cnt_r_area / tot_area
yperc = cnt_y / tot_area
gperc = cnt_g / tot_area
glimit = 0.1
if yperc*100<10 or gperc*100<10:
    print("Fruit not detected")
else:
    if gperc > glimit:
        print(f"Unripe({gperc*100:.2f}%Unripe)")

    else:
            print(f"Ripe({yperc*100:.2f}%ripe)")
```

- Calculates the total area covering redness, yellowness, and greenness.
- Computes the percentages of redness, yellowness, and greenness.
- Adjusts limits for ripeness classification and determines whether the fruit is ripe or unripe.
- Prints the result.

5.2 Output screen

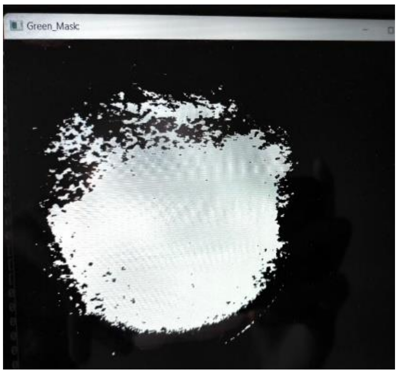


Green Apple

Fig 5.2.1

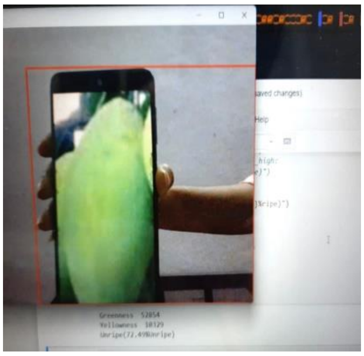
Yellow mask

Fig 5.2.2



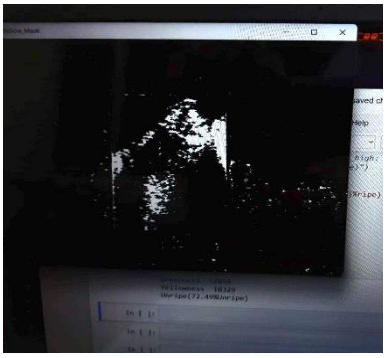
Green mask

Fig 5.2.3



Green Mango

Fig 5.2.4



Yellow mask

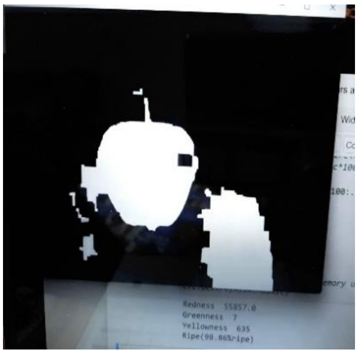
Fig 5.2.5

Green mask

Fig 5.2.6

Red Apple

Fig 5.2.7



Yellow mask

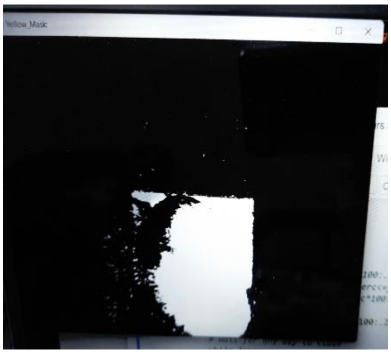
Fig 5.2.8

Green mask

Fig 5.2.9

Mango

Fig 5.2.10

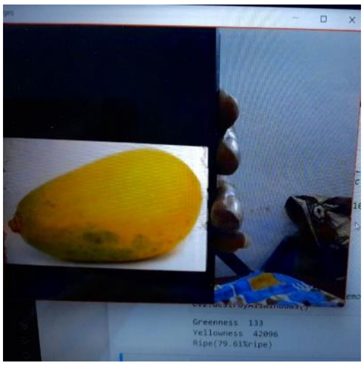


Yellow mask

Fig 5.2.11

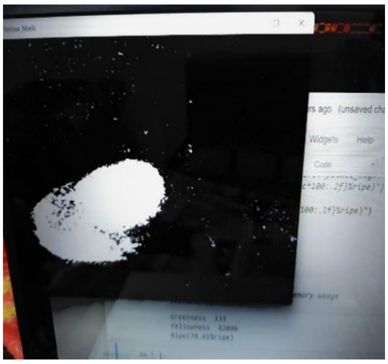
Banana

Fig 5.2.12



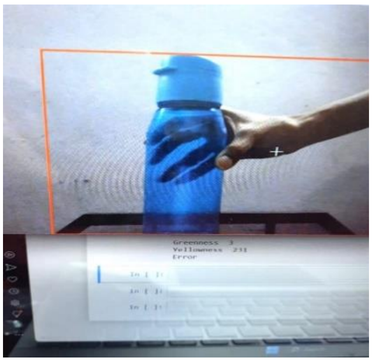
Papaya

Fig 5.2.13



Yellow mask

Fig 5.2.14



Object

Fig 5.2.15

5.3 Result Analysis

The result analysis of fruit ripeness detection using OpenCV involves evaluating the accuracy, precision, and recall of the model's predictions, assessing its ability to generalize across diverse datasets and environmental conditions. Additionally, considerations such as processing speed, resource efficiency, and qualitative performance on different fruit varieties contribute to a comprehensive evaluation, ensuring the system's reliability and practicality in real-world applications within the agricultural and food industry.

CHAPTER 6
6. FUTURE WORK

The evolution of fruit ripeness detection via OpenCV presents an exciting trajectory poised for multifaceted advancements. Integrating cutting-edge deep learning models, notably Convolutional Neural Networks (CNNs), stands as a pivotal avenue for elevating the system's capabilities. This integration promises heightened precision in feature extraction and classification, allowing for nuanced assessments of fruit ripeness levels.

Efforts to streamline real-time processing form another critical frontier, where optimization techniques and hardware acceleration are focal points. Such enhancements aim to significantly boost the system's speed and efficiency, thereby enabling swift analyses even in dynamic environments.

Expanding the system's purview beyond singular fruit types represents a fundamental shift toward inclusivity. This necessitates the development of adaptable and generalized models capable of discerning and categorizing various fruit characteristics accurately. Comprehensive and diverse datasets play a crucial role in this pursuit, enabling robust model training by encompassing a spectrum of lighting conditions, fruit sizes, and ripeness gradients.

Augmenting ripeness assessment metrics beyond traditional color and shape analyses marks a strategic leap forward. Exploring additional factors like texture analysis or spectroscopy promises a more holistic evaluation of fruit ripeness, potentially unlocking deeper insights into quality. Ensuring the system's resilience in diverse environmental conditions—adapting to varying lighting scenarios or irregular fruit shapes—remains a cornerstone of further development. Supplementing visual analysis with additional sensory inputs, such as ethylene gas sensors or chemical indicators, holds promise for refining accuracy and precision in ripeness determination.

Lastly, optimizing models for deployment in resource-constrained environments is pivotal for democratizing access to this technology. Aligning with OpenCV's adaptable nature, such optimizations aim to ensure the viability of the system across a spectrum of operational settings, from sophisticated facilities to remote agricultural landscapes.

CHAPTER 7

7. CONCLUSION

In conclusion, the trajectory of fruit ripeness detection through OpenCV is poised for significant advancements and widespread application. Integrating cutting-edge technologies such as deep learning models, real-time processing optimizations, and IoT integration holds the promise of revolutionizing fruit management systems. The future of this technology lies in its ability to transcend singular fruit types, leveraging adaptable and generalized models to discern diverse fruit characteristics accurately. This evolution necessitates robust dataset curation encompassing various environmental conditions and ripeness levels. Th e augmentation of ripeness assessment metrics, beyond conventional color and shape analyses, signifies a shift toward holistic evaluation methodologies. Simultaneously, user-centric design principles drive accessibility, empowering stakeholders across industries. Robustness against environmental variables, integration of additional sensory inputs, and optimization for diverse operational landscapes emerge as pivotal focal points for further development. Ultimately, these advancements aim to democratize access to accurate and efficient fruit ripeness detection, catering to both industrial and agricultural sectors, and contributing to enhanced productivity and quality in fruit management practices. As OpenCV continues to evolve, its adaptability and comprehensive toolset are instrumental in propelling the frontiers of fruit ripeness detection technology.

CHAPTER 8

8. REFERENCES

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