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A Review: Comparative Analysis of Computer Vision Techniques for Defect Detection and Categorization in Bananas and Apples

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A B S T R A C T

Detection and classification of these defects in bananas and apples using computer vision techniques are crucial for quality control, sorting processes, and ensuring consumer satisfaction. By accurately identifying and categorizing these defects, producers and retailers can take appropriate measures to minimize waste, maintain product quality, and enhance the overall marketability of fruits. This review offers a comprehensive summary of recent studies that have utilized computer vision techniques for the identification and categorization of defects in bananas and apples. It specifically investigates the distinctions between the two fruits in terms of the outcomes obtained from employing similar computer vision methods. The reviewed research highlights the effectiveness of various techniques, such as support vector machines, deep learning methods, and machine learning algorithms, in accurately detecting defects in both bananas and apples. By analyzing the results obtained from these techniques, the review aims to uncover any contrasting patterns or variations between the two fruits. Ultimately, this research provides valuable insights into the unique characteristics and challenges associated with defect detection in bananas and apples using computer vision methods.

مراجعة: التحليل المقارن لتقنيات الرؤية الحاسوبية للكشف عن العيوب وتصنيفها في الموزوالتفاح

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الكلمات المفتاحية:
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الملخص

يعد اكتشاف وتصنيف هذه العيوب في الموز والتفاح باستخدام تقنيات الرؤية الحاسوبية أمرًا بالغ الأهمية لمراقبة الجودة وعمليات الفرز وضمان رضا المستهلك. ومن خلال تحديد هذه العيوب وتصنيفها بدقة، يمكن للمنتجين وتجار التجزئة اتخاذ التدابير المناسبة لتقليل الهدر، والحفاظ على جودة المنتج، وتعزيز قابلية تسويق الفواكه بشكل عام. تقدم هذه المراجعة ملخصًا شاملاً للدراسات الحديثة التي استخدمت تقنيات الرؤية الحاسوبية لتحديد وتصنيف العيوب في الموز والتفاح. وهو يبحث على وجه التحديد في الفروق بين الثمرتين من حيث النتائج التي تم الحصول عليها من استخدام أساليب رؤية الكمبيوتر المماثلة. يسلط البحث الذي تمت مراجعته الضوء على فعالية التقنيات المختلفة، مثل آلات الدعم المتجهة، وطرق التعلم العميق، وخوارزميات التعلم الآلي، في الكشف الدقيق عن العيوب في كل من الموز والتفاح. ومن خلال تحليل النتائج التي تم الحصول عليها من هذه التقنيات، تهدف المراجعة إلى الكشف عن أي أنماط أو اختلافات متناقضة بين الثمرتين. في النهاية، يقدم هذا البحث رؤى قيمة حول الخصائص والتحديات الفريدة المرتبطة باكتشاف العيوب في الموز والتفاح باستخدام طرق الرؤية الحاسوبية.

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1. Introduction

Computer vision has emerged as a promising field in the agricultural industry, particularly in the detection and classification of defects on fruits such as bananas and apples. Traditional manual grading methods have proven to be laborious and inconsistent, leading to the need for automated systems that can accurately identify and classify defects. This review aims to explore the advancements and research conducted in the area of computer vision for detecting and classifying defects on bananas and apples.

Several studies have been conducted in this domain, focusing on different aspects of computer vision and machine learning techniques. For instance, Zhu and Spachos proposed a food grading system using support vector machine and YOLOv3 methods. They demonstrated the effectiveness of these techniques in accurately grading food items [1]. Similarly, Dat et al. developed a computer vision system for detecting and classifying defects on exported banana leaves. Their study highlighted the potential of computer vision in improving the quality control process [2].

In recent years, deep learning techniques have gained significant attention in the field of computer vision. Salim et al. investigated a food recognition system using deep learning algorithms. They showcased the capabilities of these algorithms in accurately identifying different food items [3]. Athiraja and Vijayakumar focused specifically on banana disease diagnosis using computer vision and machine learning methods. Their study demonstrated the potential of these techniques in early detection of diseases and improving crop management practices [4].

Apart from disease detection, computer vision techniques have also been utilized for size estimation and sorting of fruits. Hu et al. proposed a method for determining banana size based on computer vision. Their study highlighted the feasibility of using image-processing techniques for accurate size estimation [5]. Mahendran et al. and Chopde et al. also discussed the application of computer vision in sorting and grading of fruits and vegetables, emphasizing the potential for automation in the agricultural industry [7] [8].

In conclusion, this review aims to provide an overview of the advancements in computer vision for detecting and classifying defects on bananas and apples. The selected studies highlight the effectiveness of various techniques, including support vector machines, deep learning algorithms, and image processing methods. The findings of these studies demonstrate the potential of computer vision in improving the quality control process and enhancing agricultural practices in the fruit industry.

In this paper, we reviewed a large number of recent articles on the computer vision of detection and classification defects on bananas and apples, detailing the structure, training methods, and final assessment results of computer vision for the processing of images, spectra, text, and other details in each reviewed article. The following is how the paper is structured: Section 1 describes the methodology, and Section 2 discusses previous studies related to detecting and classifying defects in fruits using computer vision. The cited papers present a range of approaches, including support vector machines, deep learning algorithms, and image processing techniques, that have been applied in this field. Section 3 focuses specifically on the detection and classification of defects on bananas using computer vision, discussing the specific challenges and techniques employed in this context. Section 4 delves into the detection and classification of defects on apples using computer vision, exploring the specific methodologies and advancements in this area. Section 5 explains results, benefits and drawbacks while Section 6 presents the conclusion and section 7 presents Future work. By following this structured approach, the paper aims to provide a comprehensive overview of the current state of research and advancements in the field of computer vision for the detection and classification of defects on bananas and apples.

The motivation of the work is to provide a comprehensive summary and analysis of recent studies that have used computer vision techniques to identify and classify defects in bananas and apples. The focus is on comparing the results of using similar computer vision methods to detect defects in these two fruits. The review specifically looks at how effective techniques such as support vector machines, deep learning methods, and machine learning algorithms are in detecting defects in both bananas and apples.

Ultimately, the overarching goal of this study is to contribute nuanced perspectives on the intricacies of employing computer vision techniques for defect detection in bananas and apples, shedding light on the unique challenges and opportunities presented by each fruit.

By examining and comparing the results obtained from these different techniques and knowing the extent of the impact of the difference in the types of fruits in terms of shape, color, size and other features, the review aims to reveal any distinct patterns or differences in detecting defects between bananas and apples. The ultimate goal of this research is to provide valuable insights into the unique characteristics and challenges associated with using computer vision methods to detect defects in bananas and apples.

In summary, the work aims to provide a comparative analysis of computer vision techniques for defect detection and categorization in bananas and apples, shedding light on the effectiveness of different methods and the nuances in detecting defects in these two fruits.

2. Methodology

The methodology used is a comprehensive review and examination of recent studies that have leveraged computer vision techniques to identify defects in bananas and apples. The focus is on comparing results derived from using similar computer vision methodologies on these two fruits.

Several key techniques, including support vector machines, deep learning methods, and various machine learning algorithms, are examined to evaluate their effectiveness in accurately identifying defects in both bananas and apples.

Through a meticulous analysis of the results yielded by these methodologies, this review aims to unveil any discernible patterns or differences between the detection of defects in bananas versus apples. By delving into these distinctions and similarities, the research seeks to provide valuable insights into the distinct characteristics and challenges inherent in utilizing computer vision methods for defect detection in these fruits.

Search Strategy and Databases:

• Databases: The search was conducted in relevant scientific databases such as IEEE Xplore, Scopus, and Google Scholar.

•Keywords: The search terms used include combinations of keywords such as "banana," "apple," "defect detection," "defect classification," "computer vision,"" machine learning," and "deep learning."

•Exclusion of Irrelevant Studies: Papers that focused on topics unrelated to defect detection and classification on bananas and apples or did not use computer vision techniques were excluded.

2.1 Image dataset

Banana and apple defects can be identified using various publicly available datasets, such as the Banana Leaf Disease Identification Dataset, the Banana and Apple Disease Detection Dataset, Leaf Disease Detection Dataset, and an image dataset containing bananas and apples with defects. These datasets are valuable for constructing and testing machine-learning models designed to detect defects in bananas. Utilizing such datasets can aid researchers and model developers in creating algorithms that are more precise.

Furthermore, it is advisable to have a diverse collection of photos captured from different perspectives, angles, and backgrounds. Since these datasets might not always be accessible to the public, the most effective approach is to curate your dataset by gathering images that show case both defective and non-defective instances. Figures 1 and 2 are examples of images of apples and bananas.

Fig.1 Sample of images dataset for good and bad products of apples.

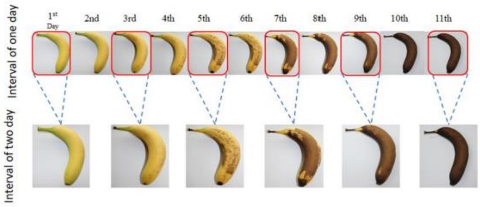

Fig.2 Sample of images dataset for good and bad products of Banana.

3. RELATED WORKS

Bananas and apples, like many fruits, can be susceptible to various defects that can affect their appearance, quality, and shelf life. Some of the common defects found in bananas and apples are as follows:

3.1. Detection and Classification of Defects on Bananas

Bananas can exhibit various quality issues. Bruises, resulting from impacts during handling, transportation, or storage, lead to visible dark spots or discoloration on the skin. Scars may appear due to mechanical damage, insect infestations, or environmental factors, causing marks or indentations on the fruit's surface. Variances in ripeness levels within a batch can create inconsistencies in color, firmness, and flavor. Additionally, surface spots, blemishes, or fungal infections can develop due to factors like humidity, temperature fluctuations, or pathogens, affecting the bananas' visual appeal.

Zhu and Spachos propose a food grading system using SVM and YOLOv3 methods [1]. The system aims to classify different food items based on their quality attributes. Dat, Hai, and Thinh focus on the detection and classification of defects on exported banana leaves using computer vision [2]. Their approach involves image preprocessing, feature extraction, and classification algorithms.

Salim et al. conduct a study on a food recognition system using deep learning techniques [3]. They utilize a deep learning model to recognize and classify different food items based on their visual appearance. Athiraja and Vijayakumar propose a banana disease diagnosis system using computer vision and machine learning techniques [4]. Their system identifies and classifies different diseases affecting banana plants.

Hu et al. focus on determining the size of bananas using computer vision [5]. They describe a method that involves image acquisition, preprocessing, feature extraction, and size estimation algorithms. Tripathi and Maktedar present a survey on the role of computer vision in horticulture, discussing various applications in quality inspection, grading, sorting, and disease detection [6].

Mahendran, Jayashree, and Alagusundaram discuss the application of computer vision techniques in sorting and grading of fruits and vegetables [7]. They highlight the importance of automated grading systems and present different algorithms for sorting based on size, color, and shape. Chopde et al. provide a review of computer vision systems in quality inspection of fruits and vegetables, addressing defect detection, ripeness estimation, and quality assessment [8].

Ismail and Malik propose a real-time visual inspection system for grading fruits using computer vision and deep learning techniques [9]. They develop a system that captures images, extracts features, and uses deep learning algorithms for classification and grading. Fu et al. introduce Yolo-banana, a lightweight neural network for rapid detection of banana bunches and stalks in the natural environment [10].

The paper by Liu Yang et al. focuses on the automatic detection of banana maturity using image recognition technology in agricultural production. The researchers emphasize the significance of machine vision technology and deep learning in non-destructive inspection of agricultural products. Specifically, they address the issue of economic loss caused by damage and unjustified handling of bananas during the ripening process.

To tackle this problem, the researchers propose a high-efficiency banana ripeness recognition model based on a convolutional neural network (CNN) and transfer learning. They collect a dataset consisting of banana photos at different ripening stages and apply data augmentation techniques to enhance the dataset. The weights and parameters of four pre-trained models from the original ImageNet dataset are loaded and fine-tuned to suit the banana dataset.[22]. figur3 displays the original image of the RGB image, the converted HSI image, In addition, the photo after the morphological procedure of the banana.[25].

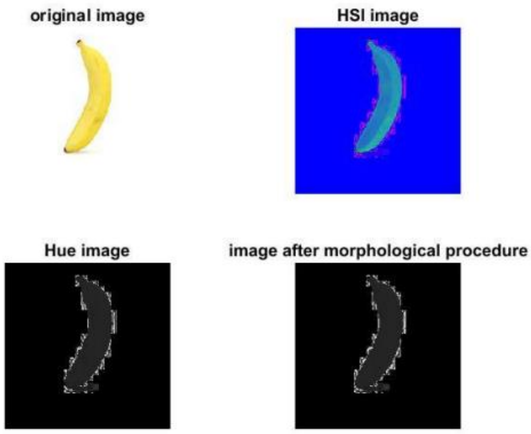

Figure 4. RGB image, original image, and processing.

3.2. Detection and Classification of Defects on Apples

Browning or enzymatic browning occurs when apples are exposed to oxygen, leading to the discoloration of the flesh and skin, often caused by cuts, bruises, or improper handling.

Bruising: Similar to bananas, bruises on apples can result from physical impacts during harvesting, packing, or transportation, manifesting as dark or soft spots on the fruit's surface.

Scab: Apple scab is a common fungal disease that causes dark, scaly lesions on the fruit's skin, affecting its appearance and potentially reducing its market value.

Internal browning can occur in apples due to chilling injury, storage conditions, or physiological disorders, leading to brown discoloration inside the fruit without external symptoms.

Mold growth and decay can affect apples when exposed to moisture, poor ventilation, or fungal spores, resulting in fuzzy patches, softening, and unpleasant odors.

Mohammadi Baneh et al. discuss the integration of mechatronic components and computer vision in apple sorting machines [11]. Wang et al. propose an automated crop yield estimation system for apple orchards using computer vision techniques [12]. Bargoti and Underwood present an image segmentation approach for fruit detection and yield estimation in apple orchards [13].

Wang et al. propose a real-time apple stem/calyx recognition system using the YOLO-V5 algorithm [14]. Abbaspour-Gilandeh et al. investigate the feasibility of using computer vision and AI techniques for the detection of apple pests and diseases [15]. Tanco et al. propose a computer vision-based system for apple detection in crops [16].

Cardenas-Perez et al. evaluate the ripening stages of apples using a computer vision system [17]. Zhang et al. propose a computer vision-based method for estimating the volume and weight of apples using 3D reconstruction [18]. Li et al. develop a computer vision-based system for apple surface defect detection [19]. Moallem et al. propose a computer vision-based grading system for Golden Delicious apples [20]. Al-Marakeby et al. propose a fast quality inspection system for food products using computer vision [21].figur4 displays the original image of the RGB image, the converted HSI image,

In addition, the photo after the morphological procedure of the apple.[25].

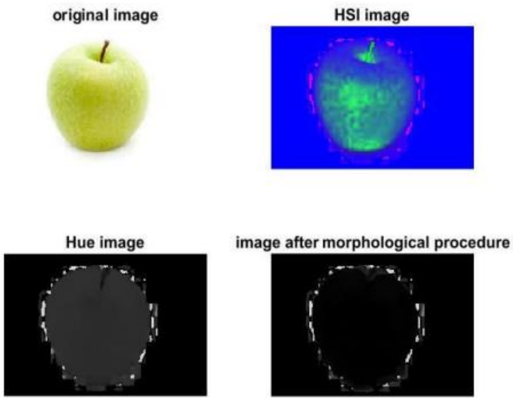

Figure 4. RGB image, original image, and processing.

4. Comparative Analysis

In this comparative analysis, we will review the different computer vision techniques used for defect detection in bananas and apples. We will discuss the key findings and approaches from the selected studies.

Mohammadi Baneh et al. (2018) focused on the integration of computer vision systems into apple sorting machines. They highlighted the importance of mechatronic components for efficient fruit grading and quality control. Although the study doesn't specifically mention defect detection, it provides insights into the overall implementation of computer vision in apple sorting processes. [11]

Wang et al. (2013) proposed an automated crop yield estimation method for apple orchards. While not solely focused on defect detection, the study demonstrates the use of computer vision techniques, such as image analysis and machine learning, to estimate apple yields accurately. This approach indirectly contributes to identifying and assessing fruit quality, including defect detection. [12]

Bargoti and Underwood (2017) developed an image segmentation approach for fruit detection and yield estimation in apple orchards. The study focuses on using computer vision techniques to identify and quantify fruit clusters. Although not explicitly about defect detection, accurate fruit detection can indirectly contribute to identifying and assessing defects in apples.[13]

Wang et al. (2022) presented a real-time recognition system using the YOLO-V5 algorithm to detect apple stem/calyx. While this study does not specifically address defect detection, it highlights the application of computer vision for automating processes in the fruit industry. Accurate detection and recognition of apple stem/calyx can indirectly contribute to defect detection.[14]

Abbaspour-Gilandeh et al. (2022) investigated the feasibility of using computer vision and artificial intelligence techniques for detecting apple pests and diseases. Although the focus is on pests and diseases, the study demonstrates the potential of computer vision for early detection and monitoring of agricultural issues, which can indirectly contribute to defect detection. [15]

Tanco et al. (2018) proposed a computer vision-based system specifically for apple detection in crops. The study focuses on using image processing and machine learning techniques to identify apple fruits in complex agricultural environments. While not explicitly about defect detection, accurate fruit detection can indirectly contribute to identifying and assessing defects in apples. [16]

Cardenas-Perez et al. (2017) evaluated the ripening stages of Golden Delicious apples using a computer vision system. The study demonstrates the use of computer vision techniques to assess fruit quality attributes based on visual appearance. While not directly focused on defects, the ability to analyse fruit attributes can indirectly contribute to defect detection. [17]

Zhang et al. (2020) developed a computer vision-based approach for estimating the volume and weight of apples using 3D reconstruction and noncontact measuring methods. Although not specifically about defect detection, accurate measurement of fruit attributes can indirectly contribute to identifying and assessing defects in apples.[18]

Li et al. (2002) proposed a computer vision-based system for apple surface defect detection. The study focuses on using image analysis techniques to identify and classify surface defects on apple fruits. This study directly addresses the detection of surface defects in apples.[19]

Moallem et al. (2017) developed a computer vision-based apple grading system specifically for Golden Delicious apples. The study emphasizes the use of surface features extracted from images for fruit grading purposes. While not solely focused on defect detection, grading based on surface features can indirectly contribute to identifying and assessing defects in apples.[20]

The study conducted by Zheng et al. (2024) revolves around the application of computer vision technology for apple detection and maturity assessment. The researchers utilize a range of techniques and algorithms to accomplish their goals. Firstly, the YOLOv7 algorithm is utilized for target detection of apples. This algorithm is capable of accurately detecting the apples in the images, and the number of apples present is counted to generate a distribution histogram of the apple count.

Next, the position of each apple is detected using the YOLOv7 algorithm, and a 2D scatter plot of the geometric coordinates of the apples is created. This helps in visualizing the spatial distribution of the apples. [23]

In general, computer vision algorithms have shown promising results in both apple and banana applications, including grading, defect detection, size estimation, and pest detection. However, the specific accuracy and performance can vary depending on the specific algorithms and techniques used in each study. These papers cover a range of tasks such as food grading, defect detection, disease diagnosis, size estimation, sorting and grading, yield **estimation**, ripening stage evaluation, pest and disease detection, and surface defect detection. Various techniques and algorithms are used, including support vector machines (SVM), YOLOv3, deep learning, computer vision, machine learning, neural networks, image segmentation, 3D reconstruction, and more. Table1 and Table2 provides a Comparative analysis of the techniques and algorithms used in each study for their respective tasks.

Table 1: Summary Comparative analysis of the techniques and algorithms used of Banana.

Paper	Task	Techniques/Algorithms Used
[1] (2020)	Food grading	Support Vector Machine (SVM), YOLOv3
[2] (2019)	Defect detection	Computer vision techniques were utilized for the detection and classification of defects on exported banana leaves.
[3] (2021)	Food recognition	Deep learning
[4] (2021)	Disease diagnosis	Image processing, feature extraction and classification algorithms such as Support Vector Machines (SVM), Random Forest, or Convolutional Neural Networks (CNN).
[5] (2015)	Size estimation	Computer vision techniques, image-processing algorithms for size estimation, possibly utilizing methods like edge detection, contour analysis, or template matching.
[7] (2012)	Sorting and grading	Computer vision
[9] (2022)	Grading	Computer vision, deep learning
[10] (2022)	Bunch and stalk detection	Lightweight neural network
[22](2024)	Automatic Detection of Banana Maturity	CNN models, ResNet 34, ResNet 101, VGG 16, and VGG 19, are trained based on transfer learning.

Table 2: Summary Comparative analysis of the techniques and algorithms used Apple.

Paper	Task	Techniques/Algorithms Used

[11] (2018)	Apple sorting	Computer vision, mechatronic components
[12] (2013)	Crop yield estimation	Computer vision, automated techniques
[13] (2017)	Fruit detection, yield estimation	Image segmentation, computer vision
[14] (2022)	Apple stem/calyx recognition	YOLO-V5 algorithm, computer vision
[15] (2022)	Pest and disease detection	Computer vision, artificial intelligence techniques
[16] (2022)	Apple detection	Computer vision, image processing
[17] (2017)	Ripening stage evaluation	Computer vision, image processing
[18] (2020)	Volume and weight estimation	Computer vision, 3D reconstruction, noncontact measuring
[19] (2002)	Surface defect detection	Computer vision, image processing
[20] (2017)	Apple grading	Computer vision, image processing
[23](2024)	apple detection and maturity assessment	YOLOv7 algorithm
[24](2023)	Classifying apple fruit quality.	(SVM, Random Forest, K-NN, Decision Tree, and Logistic Regression

5. Result

The studies on bananas and apples utilize computer vision techniques to address various aspects of the agricultural industry. While they share similarities in terms of incorporating advanced techniques like computer vision and machine learning, there are also differences in their focus and methodology. Summary of the benefits and drawbacks of the mentioned techniques in Table3.

Table3: Summary of the benefits and drawbacks for computer vision techniques.

Technique	Benefits	Drawbacks
Food grading system using SVM and YOLOv3 methods	Accurate detection and classification, handling complex scenes, high detection speed	Dependence on training data quality, manual feature engineering for SVM
Detection and classification of defects on exported banana leaves	Automated and objective approach, improved efficiency of quality control	Accuracy may depend on defect complexity and variability, performance affected by lighting and image quality
Banana disease diagnosis using computer vision and machine learning	Early detection and diagnosis, timely intervention and prevention, learning disease patterns	Accuracy depends on training data quality, influenced by variations in symptoms and environmental conditions
Determining banana size using computer vision	Accurate measurement, eliminating manual effort	Accuracy affected by banana positioning and lighting variations

In terms of findings, the studies on both bananas and apples emphasize the potential of computer vision in improving efficiency, accuracy, and automation in different aspects of the agricultural industry. They address issues such as defect detection and classification, yield estimation, grading, size measurement, and sorting. However, each study focuses on a specific aspect, such as banana leaves, disease diagnosis, fruit size, or stem identification, which may limit their comprehensive solution for overall quality assessment or fruit grading.

The methodologies employed in the studies vary. They utilize various computer vision techniques, including image processing, object detection, and recognition algorithms. Some studies also incorporate mechatronic components to enable automated sorting and loading processes. Machine learning models are used in some studies for classification and grading tasks. However, the studies often lack detailed evaluation and comparison with existing systems or methods, as well as information on datasets used for training and performance evaluation metrics employed. Real-world applicability and challenges, such as variations in fruit appearance and lighting conditions, are also not thoroughly addressed in some studies.

In terms of critical comments, there are several weaknesses identified in the studies. These include the lack of detailed evaluation and comparison with existing systems or methods, limited scope, lack of information on datasets and performance evaluation metrics, and inadequate consideration of real-world challenges and applicability. Some studies also fail to address issues related to durability, robustness, and maintenance cost of mechatronic systems.fig1 shows trends in Apple and Banana's computer vision research Banana and fig2 shows trends in apple a banana together.

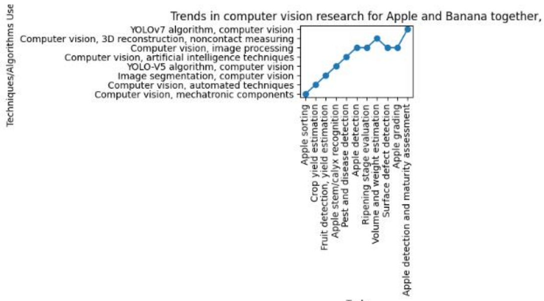

Fig 1. Trends in Computer Vision Research for Apple. and Banana**.**

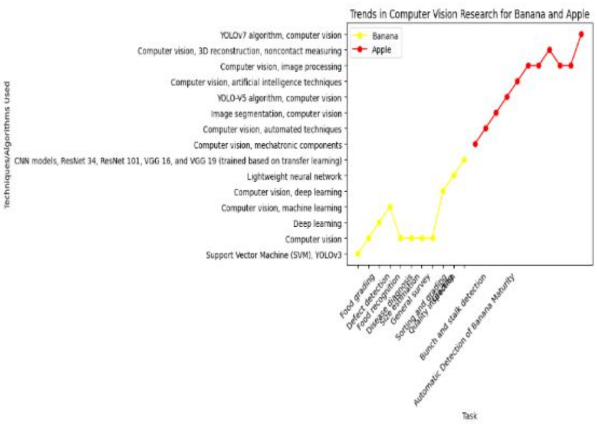

Fig 2. Trends in Computer Vision Research for Apple and Banana Together.

5.1 Optimizing Camera and Lighting Specifications for Accurate Food Grading and Inspection

Based on the research papers studied in this research, we noticed that the most widely used camera for food classification and inspection is the high-resolution digital camera. The specifications of these cameras vary, but they are usually a minimum of 5MP and can go up to 20MP. These cameras are able to capture detailed images of fruits and vegetables, which is important for accurate grading and defect detection. In terms of lighting, most of these papers mention the use of artificial lighting, such as LED or fluorescent lights, to provide consistent and controlled lighting for the images. This helps to avoid shadows and provide clear images for analysis.

The distance between the camera and the objects being inspected also plays a crucial role in achieving high accuracy. Generally, a distance of around 1 meter is recommended for optimal results. This ensures that the camera captures a clear image of the entire object, without any distortion or blurriness.

Importantly, the use of high-resolution cameras and controlled lighting is essential to achieve accurate and reliable results in food grading and inspection systems.

One of the effective types of lighting in improving the quality of images is bright and even lighting. As I mentioned in previous research papers, the use of artificial lighting such as warm and cold lighting helps improve and unify the lighting on the image and avoid unwanted shadows.

There are many techniques used to determine and improve lighting in images, including backlighting, sidelighting, main lighting and auxiliary lighting. The preference between these techniques depends on the type of camera, the purpose of photography, and the type of lighting available.

To improve side lighting in photography, available side lighting lamps such as halogen lamps or neon lighting can be used. The lighting angle can also be adjusted and determined precisely to achieve ideal side lighting in the image.

5.2 The Impact of Fruit Shape, Size, Angles and Location on Image Quality and Classification Accuracy.

Through these studies, we can say that the shape of fruit plays an important role in image classification accuracy and quality. For example, the round shape of an apple makes it easier to capture a clear image and increases accuracy, while the curved shape of a banana may make it difficult to capture a clear image and affect classification accuracy. The size of the fruit can also affect image quality and classification accuracy, as a larger fruit may be difficult to capture in its entirety, while a smaller fruit may be easier to photograph and estimate size. Additionally, angles and location can also impact image quality and classification accuracy. If the location or angle is not suitable, it can result in shadows or interference in the image, affecting classification accuracy.

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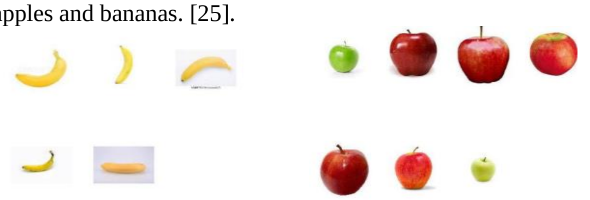

Figure 5 shows the difference in shape between the two fruits**.**

5.3. Some key points to consider in comparing bananas and apples using computer vision and machine learning techniques:

Detection and classification: Studies have shown that both fruits can be accurately detected and classified using computer vision and machine learning techniques. However, the methods used may vary, with some studies using support vector machines and others using deep learning algorithms like YOLO.

Quality inspection: Both fruits have been successfully graded and inspected using computer vision, with some studies focusing on surface defects and others on ripeness and maturity assessment.

Crop estimation: Computer vision has been used to estimate the yield of both bananas and apples in orchards, with promising results. This can help farmers in planning and managing their crops more efficiently.

Speed and efficiency: The use of computer vision and machine learning has shown to be faster and more efficient in detecting and grading fruits compared to traditional methods, which can help in reducing labor costs and increasing productivity.

Variations in methods: While some studies have focused on a specific type of fruit, others have compared different varieties within the same fruit type. This shows the potential for using computer vision in a wide range of fruits and vegetables, including bananas and apples.

Finally,, both bananas and apples have shown promising results in terms of detection, grading, and quality inspection using computer vision and machine learning techniques. However, the specific methods and applications may vary depending on the type of fruit and its characteristics.

6. Conclusion

In conclusion, the reviewed papers provide a comprehensive overview of computer vision techniques for defect detection in bananas and apples. These studies highlight the importance of non-destructive inspection and quality assessment in agricultural production. The use of deep learning, machine learning, and image recognition technologies have shown promising results in identifying defects, assessing ripeness, and grading fruits.

The papers demonstrate the effectiveness of various computer vision techniques, such as support vector machines, YOLOv3, and deep learning models like CNNs, in detecting defects and assessing the quality of bananas and apples. They also explore the application of computer vision in other aspects, such as size determination, pest and disease detection, and yield estimation.

By addressing these challenges and limitations, the utilization of computer vision in the agricultural industry can be further enhanced, leading to improved productivity, quality control, and efficiency in the cultivation and processing of bananas and apples.

7. Future Work

Based on the findings from these papers, several recommendations can be made for future research:

Further exploration of different computer vision techniques: While the reviewed papers cover a wide range of techniques, there are still opportunities to investigate and compare the performance of other algorithms and models in defect detection and quality assessment of bananas and apples.

Dataset diversity and size the availability of diverse and large-scale datasets is crucial for training accurate and robust computer vision models. Future research should focus on creating comprehensive and representative datasets that encompass various defect types, ripening stages, and environmental conditions.

Real-time and practical implementation: To facilitate the practical application of computer vision systems in agricultural production, researchers should focus on developing real-time and cost-effective solutions. This includes optimizing algorithms for faster processing, integrating hardware components, and considering the scalability of the proposed systems.

Expanding the dataset and focusing on enhancing dataset diversity by integrating variations in lighting conditions, backgrounds, and diverse types of defects to strengthen the model's robustness.

Integrating multiple sensors such as combining RGB cameras and hyperspectral imaging data to obtain richer defect information and enhance detection accuracy. Utilizing advanced machine learning models and exploring deep learning architectures and ensemble methods to enhance the performance of defect detection models. Real-time systems and developing swift and accurate systems for defect detection in real-time, particularly beneficial in industrial environments.

Automation using robots and streamlining fruit processing by integrating defect detection algorithms with automated sorting and classification systems using robots.

Investigating domain adaptation and transfer learning to enhance model generalization across different fruit species and environmental conditions is the focus of this study. The insights gained from defect detection and quality assessment in bananas and apples can be utilized in other fruits and agricultural products. Future research should delve into the transferability and adaptability of computer vision technologies across different crops and commodities. The application of these modern technologies in the agricultural sector in Libya aims to raise production efficiency, reduce labor, and quickly detect defects and diseases.

7. Abbreviations and Acronyms

Here are the abbreviations and acronyms used in the provided references:

SVM - Support Vector Machine

YOLOv3 - You Only Look Once version 3

CV - Computer Vision
IEEE - Institute of Electrical and Electronics Engineers
ICSSE - International Conference on System Science and Engineering
IOP - Institute of Physics Publishing
AIHC - Ambient Intelligence and Humanized Computing
IJFP - International Journal of Food Properties
IPA - Information Processing in Agriculture
JFPTE - Journal of Food Process. Technol
AR - Agricultural Reviews
JFMC - Journal of Food Measurement and Characterization
ER - Experimental Robotics
JFR - Journal of Field Robotics
PBT - Postharvest Biology and Technology
AS - Applied Sciences
VISIGRAPP - International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications
BE - Biosystems Engineering
JS - Journal of Sensors
CEA - Computers and Electronics in Agriculture
IJARCC - International Journal of Advanced Research in Computer and Communication Engineering

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