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REAL-TIME AUTOMATIC FRUIT SORTING BASED ON THE INTEGRATION OF COMPUTER VISION METHODS AND ARTIFICIAL INTELLIGENCE MODELS

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АВТОМАТИЧЕСКАЯ СОРТИРОВКА ФРУКТОВ В РЕАЛЬНОМ ВРЕМЕНИ НА ОСНОВЕ ИНТЕГРАЦИИ МЕТОДОВ КОМПЬЮТЕРНОГО ЗРЕНИЯ И МОДЕЛЕЙ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА

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Аннотация: В данной работе рассматриваются методы обработки изображений и модели искусственного интеллекта для автоматической сортировки фруктов в промышленных условиях. Предложена система, основанная на технологиях компьютерного зрения и глубокого обучения, позволяющая осуществлять классификацию фруктов по цветовым и качественным признакам в режиме реального времени. Разработаны алгоритмы предварительной обработки изображений, сегментации и выделения признаков, а также применена модель сверточной нейронной сети для повышения точности классификации. Экспериментальные результаты показали высокую эффективность предложенного подхода, обеспечивающего стабильную работу системы и высокую точность распознавания. Полученные результаты могут быть использованы в автоматизированных производственных линиях для повышения качества продукции и снижения затрат.

Ключевые слова: компьютерное зрение, искусственный интеллект, обработка изображений, классификация фруктов, сверточные нейронные сети, автоматическая сортировка, глубокое обучение

Abstract: This paper presents image processing methods and artificial intelligence models for automatic fruit sorting in industrial environments. A system based on computer vision and deep learning technologies is proposed, enabling real-time classification of fruits according to color and quality characteristics. Image preprocessing, segmentation, and feature extraction algorithms are developed, and a convolutional neural network model is applied to improve classification accuracy. Experimental results demonstrate the effectiveness of the proposed approach, ensuring stable system performance and high recognition accuracy. The obtained results can be applied in automated production lines to improve product quality and reduce operational costs.

Keywords: computer vision, artificial intelligence, image processing, fruit classification, convolutional neural networks, automatic sorting, deep learning

Introduction: The rapid development of digital technologies has significantly influenced the modernization of agricultural production systems. In particular, the automation of fruit sorting processes has become an essential task aimed at improving product quality, reducing labor costs, and increasing overall efficiency. Traditional manual sorting methods are often characterized by subjectivity, inconsistency, and limited productivity, which makes them unsuitable for large-scale industrial applications [1,2].

The application of computer vision and artificial intelligence technologies offers new opportunities for addressing these challenges. Image processing algorithms enable the extraction and analysis of important visual features such as color, shape, and surface condition of fruits. These characteristics serve as key indicators for classification and grading processes in automated systems [2,3]. Deep learning approaches, especially convolutional neural networks (CNNs), have shown high effectiveness in solving object detection and classification problems. These models are capable of learning complex patterns from image data and can be integrated into real-time systems operating on conveyor-based sorting lines. As a result, they provide improved accuracy and reliability compared to traditional methods [4,6].

Despite these advancements, several challenges still exist. Variations in illumination, background noise, and differences in fruit size and appearance can negatively affect system performance. Therefore, it is necessary to develop robust image processing algorithms and mathematical models that ensure stable operation under varying environmental conditions [7,9].

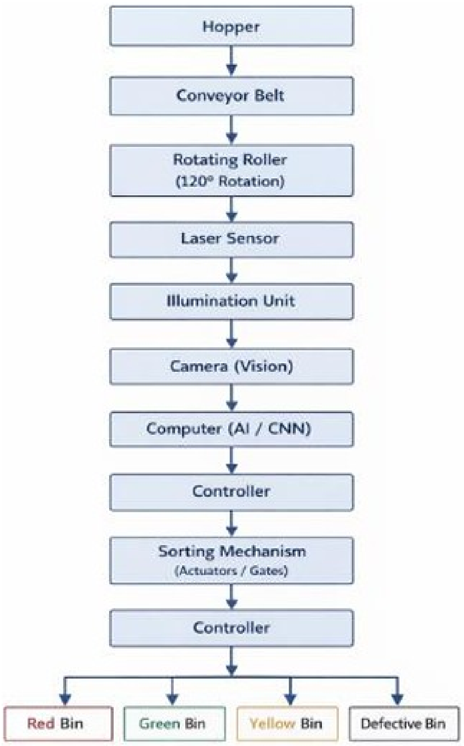

Fig 1. General block diagram of the computer vision-based fruit sorting system

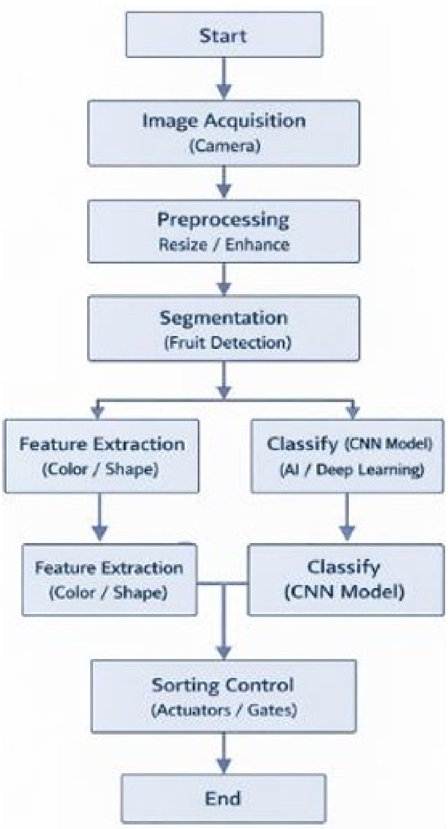

Figure 2. Image processing algorithm flowchart

The aim of this research is to develop a mathematical model and image processing algorithms for an automatic fruit sorting system based on artificial intelligence, ensuring high accuracy, efficiency, and real-time performance.

Materials and methods: The proposed automatic fruit sorting system is based on the integration of computer vision techniques and artificial intelligence models. The system is designed to operate in real-time on a conveyor-based platform, where fruits are continuously captured and analyzed using a vision sensor. The general structure of the system includes image acquisition, preprocessing, segmentation, feature extraction, and classification stages.

At the image acquisition stage, a high-resolution camera is used to capture fruit images under controlled lighting conditions. Proper illumination ensures stable color representation and reduces the impact of shadows and reflections. The captured images are then transferred to the processing unit for further analysis [1,2]. In the preprocessing stage, image enhancement techniques are applied to improve data quality. Gaussian filtering is used to reduce noise, while contrast adjustment improves visibility of important features. These operations are essential for increasing the accuracy of subsequent image processing steps [2,3].

Table 1. Main technical parameters of the system

Parameter	Value
Fruit types	Apples, oranges
Camera resolution	1920×1080 pixels
Conveyor belt speed	0.35 m/s
Rotation angle of roller	120°
Laser sensor type	Laser triangulation sensor
Illumination source	LED lights
AI model	Convolutional Neural Network (CNN)

Segmentation is performed to separate the fruit object from the background. This is achieved using thresholding methods and contour detection algorithms. As a result, the region of interest is extracted, allowing the system to focus only on relevant image areas. Feature extraction is then carried out by analyzing color components (RGB), geometric properties, and surface characteristics of the fruit [4,5]. For classification, convolutional neural networks (CNNs) are employed due to their ability to learn complex patterns from image data. The trained model categorizes fruits into predefined classes based on their visual features. The use of deep learning models improves classification accuracy and enables real-time performance in industrial environments [6,7]. The overall system architecture is illustrated in **Figure 1,** which presents the general block diagram of the computer vision system. The sequence of image processing operations is shown in **Figure 2,** representing the algorithm flowchart. To evaluate system performance, several parameters were analyzed, including processing speed, classification accuracy, and operational efficiency. The main technical parameters of the system are presented in **Table 1,** while sorting accuracy indicators are summarized in **Table 2.**

Results: The proposed automatic fruit sorting system was tested under simulated industrial conditions using a conveyor-based setup. The system demonstrated stable performance in real-time processing, successfully detecting and classifying fruits based on their visual characteristics. The developed image processing algorithm effectively extracted relevant features such as color components, shape parameters, and surface properties. The segmentation stage provided accurate separation of fruits from the backg round, which significantly improved the overall classification performance. The use of preprocessing techniques contributed to noise reduction and enhanced image clarity.

The classification model based on convolutional neural networks showed high accuracy in distinguishing between different categories of fruits. The system was able to correctly classify fruits according to predefined classes, including variations in color and surface quality. The results confirm that deep learning methods are suitable for real-time sorting tasks in industrial environments.

Table 2. Evaluation metrics for sorting accuracy

Metric	Definition
Precision	The ratio of correctly sorted fruits of a particular class to the total fruits predicted as belonging to that class.
Recall	The ratio of correctly sorted fruits of a particular class to the total actual fruits in that class.
F1-Score	The harmonic mean of precision and recall, providing a single metric for evaluating the sorting accuracy.

The system also demonstrated efficient processing speed, allowing continuous operation without delays. This makes it applicable for high-throughput production lines. The experimental results presented in Table 2 indicate a high level of classification accuracy and system reliability. The general operation of the system and its structural components are illustrated in Figure 1, while the sequence of image processing stages is shown in Figure 2. These results confirm the effectiveness of the proposed approach for automated fruit sorting.

Discussion: The obtained results demonstrate that the proposed system provides a reliable and efficient solution for automatic fruit sorting in industrial environments. The integration of image processing techniques with artificial intelligence algorithms significantly improves the accuracy and speed of classification compared to traditional methods. One of the key advantages of the system is its ability to operate in real-time conditions while maintaining high stability. The use of preprocessing and segmentation methods ensures that the system can effectively handle noise and background variations. In addition, the application of convolutional neural networks allows the model to adapt to different fruit characteristics, including variations in color, size, and surface quality.

However, certain limitations were observed during the experiments. Changes in lighting conditions and overlapping objects on the conveyor can affect the accuracy of detection and classification. These factors indicate the need for further improvement of adaptive algorithms and optimization of system parameters.

Overall, the proposed approach demonstrates strong potential for practical implementation in agricultural and industrial applications, particularly in automated sorting systems.

Conclusion: In this study, a mathematical model and image processing algorithms for automatic fruit sorting based on artificial intelligence were developed. The proposed system integrates computer vision techniques with deep learning methods to achieve accurate and real-time classification of fruits. The experimental results confirm that the system provides high classification accuracy, stable performance, and efficient processing speed. The use of convolutional neural networks enhances the system's ability to recognize complex visual patterns and improves overall reliability.

The developed approach can be effectively applied in industrial conveyor systems, contributing to increased productivity, reduced labor costs, and improved product quality. Future research will focus on improving system adaptability to varying environmental conditions and expanding the range of detectable fruit categories.

REFERENCES

1. Li X., Zhao Y. Fruit classification using deep convolutional neural networks // Computers and Electronics in Agriculture. – 2018.
2. Kamilaris A., Prenafeta-Boldú F. Deep learning in agriculture: A survey // Computers and Electronics in Agriculture. – 2018.
3. Uljaev E., Abdixalilov U., Suleymanova S., Tadjitdinov G. Analysis of Methods and Means of Fruit Sorting, Selection of a Rational Method of Fruit Sorting // International Journal of Mechatronics and Applied Mechanics. – 2025. – Issue 22, Vol. II, pp. 233–241.
4. Bargoti S., Underwood J. Deep fruit detection in orchards // IEEE Robotics and Automation Letters. – 2017.
5. Cubero S. et al. Machine vision for fruit sorting and grading // Biosystems Engineering. – 2016.
6. Rahnemoonfar M., Sheppard C. Deep learning for fruit detection and counting // Sensors. – 2017.
7. Tian Y., Yang G. Apple detection and classification using deep learning // Information Processing in Agriculture. – 2019.

8. Wang Z., Walsh K. Machine vision methods for fruit quality evaluation // Postharvest Biology and Technology. – 2018.
9. Liu S., Li J. Real-time fruit recognition using convolutional neural networks // Computers and Electronics in Agriculture. – 2020.
10. Chen C., Lin Y. Deep learning-based fruit classification methods // Artificial Intelligence in Agriculture. – 2021.