

**Software Engineering Department**

**Braude College of Engineering**

**Real time fruit grading using data mining and machine learning**

**Project code: 25-2-D-6**

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**Lidor Anfinger**

**Dror Hershcovish**

**Git repository link:** <https://github.com/Drorh473/fruit_grading.git>

**Supervisor: Mr. Ilya Zeldner**

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# Abstract

The labour-intensive nature of manual fruit grading in agricultural supply chains creates significant challenges for small-scale producers. This project introduces an innovative real-time visual inspection system that combines multi-view camera inputs with state-of-the-art deep learning models to automate fruit quality assessment. Our solution incorporates a custom-designed conveyor belt system featuring a specialized inspection box equipped with strategically positioned cameras and LED strip lighting for optimal image capture. Our approach integrates lightweight convolutional neural network (CNN) architectures to process temporal sequences of fruit images, detecting defects and classifying ripeness levels across various fruit types. The system efficiently segments multiple fruit instances from images using advanced computer vision techniques and applies sophisticated image enhancement to ensure consistent performance across varying lighting conditions.

Key words: Computer vision, Deep learning, CNN, Fruit classification, Image processing, Quality control.

# 1 Introduction

With increased consumer demand for high-quality fruits across global markets, there arises a critical need for advanced automated fruit grading systems. Traditional manual inspection approaches have demonstrated significant limitations in accuracy, consistency, and efficiency due to the labour-intensive nature of visual inspection and human-induced variability. The agricultural industry faces persistent challenges in fruit classification, grading, and quality assessment processes while attempting to meet the growing demand for consistently high-quality fresh produce in global markets.

As noted by Ismail and Malik, "traditional manual visual grading of fruits has been one of the important challenges faced by the agricultural industry due to its laborious nature as well as inconsistency in inspection and classification process" [[2]](#Reference2). Their research demonstrates that automated defects detection using computer vision and machine learning has become a promising area with direct impact on visual inspection domains.

The relevance of such technology is particularly pronounced given the agricultural labour shortages reported across major producing regions. The labour is the U.S. agricultural sector’s third largest production expense [[3]](#Reference3).

The economic impact of manual fruit grading is substantial. According to data from the Economic Research Service, labour accounts for approximately 42% of the variable production expenses for U.S. fruit and vegetable farms [[4]](#Reference4). This labour-intensive process is becoming increasingly costly as farm wages rise at a faster rate than non-farm wages, with agricultural wage growth outpacing non-agricultural wages (16% vs. 5% growth) between 2001 and 2019 [[5]](#Reference5).

Our proposed solution directly addresses these challenges by implementing an end-to-end automated inspection system that combines advanced computer vision techniques with efficient deep learning models through a comprehensive pipeline: image acquisition via a specialized mechanical conveyor system developed with a mechanical engineering student; feature extraction using ShuffleNetV2, a lightweight CNN with ReLU activation functions that balances computational efficiency with classification accuracy through innovative channel shuffle operations ; temporal processing with time-distributed feature flattening and pooling for multi-view assessment; integration of feature vectors from multiple cameras when applicable; and final classification through fully connected layers with Softmax activation function to generate probability distributions across quality classes. This integrated hardware-software approach ensures high-accuracy fruit grading capabilities while operating within the processing limitations of embedded systems commonly deployed in agricultural environments, providing consistent, objective quality assessments that exceed traditional manual inspection methods in both accuracy and efficiency.

By reducing dependency on specialized labour for quality control, our system allows agricultural operations to reallocate their limited workforce to tasks that truly require human expertise and judgment.

# 2 Background and Related Work

**2.1 Fruit Grading in Agriculture**

Fruit grading represents a critical process in the agricultural supply chain, involving the classification of fruits based on various quality parameters such as appearance, size, color, and defects. Traditional manual grading methods are labour-intensive and susceptible to inconsistencies due to human subjectivity and fatigue.

The importance of automated fruit grading systems has grown substantially with increasing global demand for consistent quality standards across agricultural produce. This inconsistency directly impacts product pricing, market acceptance, and consumer satisfaction, underscoring the need for reliable automated systems.

Current industry practices often rely on costly, high-end vision systems that are beyond the financial reach of small to medium-scale farmers and agricultural businesses. These commercial systems typically require specialized technical knowledge for operation and maintenance, creating additional barriers to adoption.

The challenge of creating affordable yet accurate grading systems has been a focus of recent research, with various approaches attempting to balance cost with performance. Our project aims to address this specific gap by developing a system that maintains high accuracy while significantly reducing implementation costs.

**2.2 Computer Vision for Fruit Quality Assessment**

Computer vision technology has revolutionized fruit quality assessment by providing objective, consistent, and efficient evaluation methods. The application of computer vision in fruit grading typically involves a sequential process:

1. **Image acquisition**: Capturing high-quality images of fruits under controlled lighting conditions to ensure consistency.
2. **Preprocessing**: Enhancing image quality through noise reduction and contract adjustments.
3. **Segmentation**: Isolating the fruit from the background to focus on relevant features.
4. **Feature extraction**: Identifying characteristics such as color, texture, and shape that correlate with quality parameters.
5. **Classification**: Assigning quality grades based on extracted features using machine learning models.

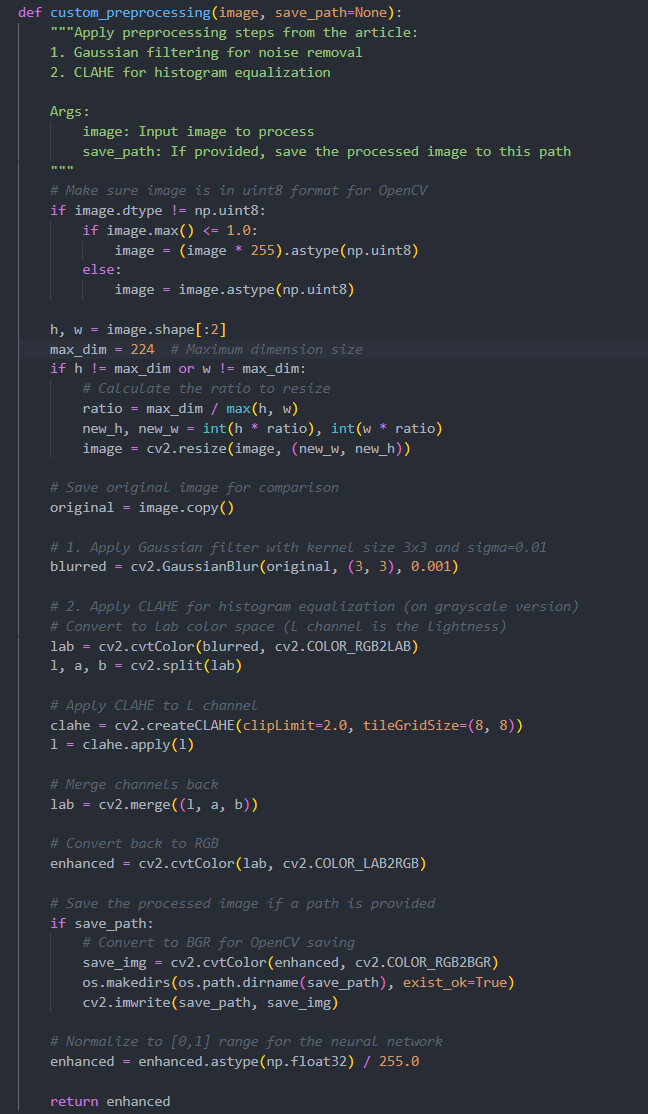
In our system implementation, we follow a similar workflow with specialized components optimized for real-time processing. Our preprocessing stage employs Gaussian filtering for noise removal and Contrast Limited Adaptive Histogram Equalization (CLAHE) for contrast enhancement, as demonstrated in our implementation:

Figure 1: Image preprocessing implementation for the fruit grading system.

For segmentation, we employ a hybrid approach combining watershed segmentation and mean shift clustering to effectively isolate fruits from complex backgrounds, even when multiple fruits are present in a single frame. This technique is particularly effective in handling the challenging scenarios encountered in real-world agricultural environments.

Recent research by Zhang et al. [7] demonstrates that combining multiple preprocessing techniques can significantly improve segmentation accuracy in varying lighting conditions, which we have incorporated into our approach. Additionally, Sun et al. [8] showed that adaptive thresholding techniques can improve segmentation performance for fruits with irregular shapes and varying surface textures.

References

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