Development of an Automated and High-throughput Peanut Maturity Evaluation System with Computer Vision and AI-assisted Technologies

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Introduction

This project aims to develop an automated and field-deployable solution for peanut maturity evaluation using computer vision and a machine-learning-guided band-selection approach. The Peanut Maturity Evaluation System (PMES) is designed as a portable, low-cost imaging platform that can rapidly assess peanut maturity based on the color characteristics of the peanut mesocarp. PMES provides a practical alternative to traditional maturity profiling methods. This system is intended to support more consistent, data-driven decision-making for peanut harvest timing.

Implementation Process

The project began with collecting peanut images using a hyperspectral imaging system (HSI), a specialized camera capable of capturing detailed color information across a wide range of wavelengths, including ultraviolet and near-infrared light. More than 300 peanut pods with varying maturity levels were collected from a small greenhouse trial (Fig. 1). The pods were pressure-washed and manually labeled into maturity categories using the maturity profile board method. The images were then used to train machine-learning (ML) models to identify the most informative color bands in peanut maturity classification. All samples were labeled into 9 maturity classes: white, yellow, dark yellow, light orange, orange, dark orange, brown, dark brown, and black.

Fig. 1. Peanut samples and hyperspectral imaging

The PMES (Fig. 2) was developed as an automated imaging system built with an industrial-grade camera housed inside a light-isolated enclosure. The enclosed design blocks outside light and ensures consistent image quality, even under varying field conditions. The system uses LED lights at three specific wavelengths selected based on the ML results from the HSI study. A custom imaging tray was designed and 3D-printed to allow fast loading and easy alignment of peanut pods, with each tray holding up to 104 pods at a time. Once loaded, the system automatically controls the lighting and imaging process. The full imaging and analysis cycle is completed in under 10 seconds. This automated workflow reduces labor effort and minimizes the potential of biased analysis, providing near-real-time feedback to support harvest decision-making.

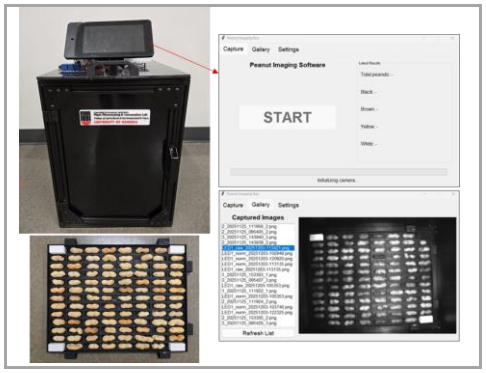

Fig. 2. Peanut Maturity Evaluation System

Data analysis and Results

Captured images are automatically calibrated to ensure consistent data quality. Image features are then analyzed using trained ML models to predict peanut maturity levels that align with the visual method. Shown in Fig. 3, R^2 of 0.888 indicates that the ML model was able to explain around 88.8% of the observed variation in peanut maturity among the samples, which then can be used to predict the days until digging.

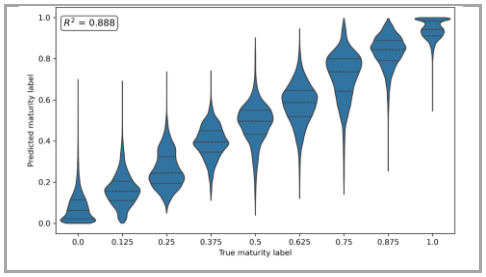

Fig. 3. Peanut maturity classification results

Conclusion:

This project developed a portable and automated system for evaluating peanut maturity using computer vision. By integrating ML-guided lighting, automated image acquisition, and data analysis, PMES delivers fast, consistent, and repeatable peanut maturity assessments that can be used directly in the field. Overall, PMES demonstrates strong potential to improve harvest timing decisions and increase profitability for peanut growers.