“Machine Learning-Based Fruit Ripening Prediction: Assessing Ripeness Levels Over Time”

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Introdction

This project aims to develop a machine learning method to predict fruit ripeness and sweetness using a non-destructive approach. This method will be highly beneficial for the food supply chain and for harvesting fruits at their optimal time

Background

The experiment involves analyzing images, including **hyperspectral images** with various wavelengths and the **reflectance** of the fruit. These images help us understand the changes occurring as a fruit progresses from **unripe to ripe to rotten.** The study will use a classifier and regression model, combining pixel difference techniques and advanced imaging technology to analyze reflectance and hyperspectral data. The project will involve building a **KNN** classifier and an **LSTM** model to predict ripeness and sweetness, ultimately combining the probabilities of both models with a **custom regression mode**l to provide the final output

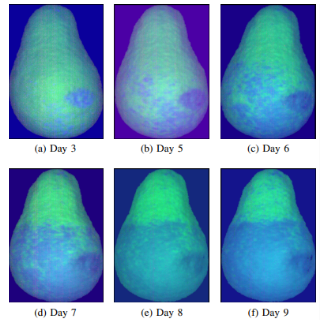
Objective and Learning Outcomes

1) Optimize the supply chain and minimize food loss during storage by working extensively on data and models:
   - Collect accurate and diverse data, including reflectance and hyperspectral images, to develop a robust model with good variability.
   - Study the changes in the inner chemical composition of the fruit over time through different ripening phases.

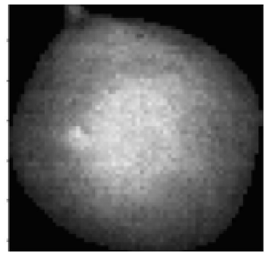
2) Build a robust model aligned with the project’s goals:
   - Identify the crucial parameters and features that affect the overall ripeness of the fruit.

Equipments

Multispectral Camera, Different varieties of fruit, Reflectance measuring device, holder for camera, halogen lamp for capturing images



Change in Internal Structure over time in Avocado



Study Methodology

Structural Change in Fruit

Part 1:

1. Reviewed relevant research papers and noted key points for analyzing photos.
2. Used hyperspectral data previously captured by another group.

Part 2:

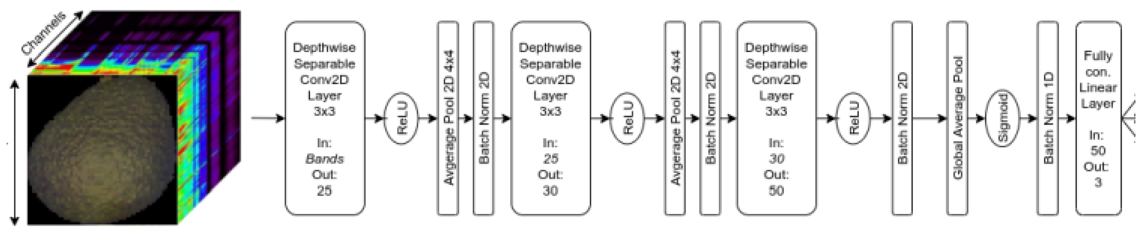
1. Converted images to greyscale and resized them for consistent orientation.
2. Computed absolute differences between images and applied a binary threshold.

Change in Reflectance of Fruit

1. Collected data on apples and oranges over 10 days using the provided apparatus.
2. Built a KNN classifier using PCA for dimensionality reduction.
3. Plotted data in Excel for manual observations.

Dry Matter in Leek

1. Collected data on leek from previous research, including wavelengths **(400-1700 nm)** and dry matter content.
2. Pre-processed data using MinMaxScaler, removed null values and analyzed heat maps to identify affected wavelengths.
3. Assigned labels based on dry matter content for each day.
4. Built a custom LSTM model to predict labels based on previous sessions



Result and Discussion

Hyperspectral Imaging Analysis

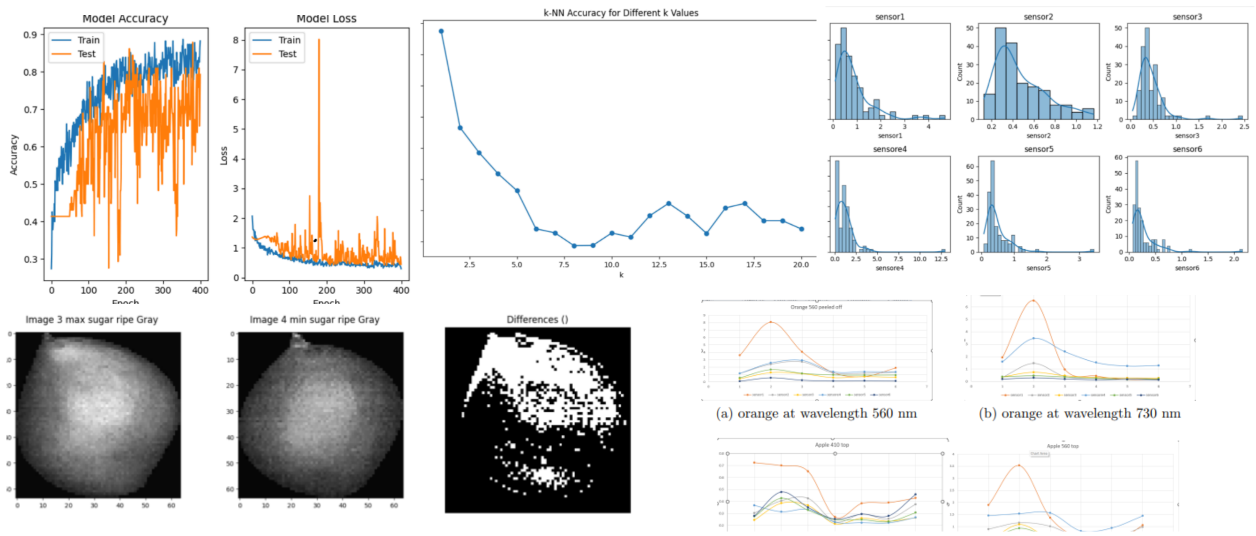
Hyperspectral imaging reveals significant internal changes in fruit at different ripeness stages. Brightness differences in images highlight structural evolution, especially from unripe to high sugar content. The method is valuable for monitoring ripeness and quality control but has limitations due to sensitivity to image orientation and other variations. Reflectance data proved more consistent and reliable for analyzing chemical composition changes.

Reflectance Data Analysis

Reflectance data from apples and oranges, collected over 10 days, showed stable values for ripe fruit, variable values for over-ripe, and erratic values for rotten stages. A KNN model using this data effectively classified ripeness stages, with higher accuracy at smaller k values, highlighting the sensor's ability to track ripeness.

Data Preprocessing and LSTM Model

Preprocessing involved transforming image data for the LSTM model. Multiple parameters influenced sugar content, achieving 80% accuracy in predicting ripeness. Large data spikes indicated high dependency among wavelengths, suggesting the need to explore different modeling approaches



Conclusion

Hyperspectral imaging reveals internal structural changes in fruit during ripening, especially from unripe to high sugar content, but its reliability is limited by **sensitivity to image orientation**. **Reflectance data** provides more consistent insights and, when used with a KNN model, accurately classifies ripeness stages, supporting automated detection systems. The **LSTM mode**l achieved around **80% accuracy** in predicting ripeness but showed high dependency among wavelengths. Future work should refine the model by exploring additional features and optimizing parameters to improve accuracy and reliability in monitoring fruit ripeness.

References

[1]**Github link**: https://github.com/Ujjwalb2/Surge_files.

[2] **Measuring the Ripeness of Fruit with Hyperspectral Imaging and Deep Learning**: https://arxiv.org/pdf/2104.09808.

[3] **Sugariness prediction of Syzygium samarangense using convolutional learning of hyperspectral images**: https://www.nature.com/articles/ s41598-022-06679-6?fromPaywallRec=false. 9

[4] **How to predict the sugariness and hardness of melons: A near-infrared hyperspectral imaging method**: https://pubmed.ncbi.nlm.nih.gov/27719929/