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Topic	Quality Assessment of Agro Products using Infrared Imaging
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Findings

- **Development of an automated AI-based quality assessment framework:** This thesis successfully developed a non-destructive, automated quality assessment system for fruits and vegetables by integrating image processing, thermal imaging, machine learning, and fuzzy logic techniques. The proposed system addressed major limitations of traditional manual inspection, including subjectivity, inconsistency, and inability to detect internal defects. By automating the grading process, the system improves reliability, efficiency, and scalability in agro-product quality evaluation.
- **Validation of thermal imaging as an effective modality for defect detection:** Thermal imaging was demonstrated to be highly effective in identifying internal bruises, physiological damage, and subtle defects that are not visible through conventional visible imaging. Temperature variations captured through thermal sensors provided meaningful indicators of quality degradation, enabling early and accurate defect detection. This confirmed thermal imaging as a powerful tool for non-invasive agricultural quality assessment.
- **Superior performance of deep learning models for fruit classification:** Multiclass classification of fruits such as apples, bananas, and oranges using visible spectrum images showed that Convolutional Neural Networks (CNNs) significantly outperformed traditional machine learning models including Support Vector Machines, Random Forests, Decision Trees, and K-Nearest Neighbors. CNNs demonstrated superior capability in automatically

extracting hierarchical image features, resulting in improved classification accuracy and robustness.

- **Improved accuracy using hybrid ANN-CNN architecture:** For thermal imaging-based potato quality classification, a hybrid model combining Artificial Neural Networks (ANN) and CNN achieved better performance than individual ANN or CNN models. This demonstrated that hybrid architectures can leverage the strengths of multiple learning paradigms to enhance classification reliability and overall system performance.
- **Importance of feature extraction and feature selection:** The study established that accurate feature extraction and careful feature selection are critical for improving classification performance. Physiological features such as color, texture, shape, size, and thermal gradients played a vital role in quality assessment. Proper selection and combination of relevant features significantly enhanced model effectiveness and classification accuracy.
- **Optimization of CNN architecture parameters for improved performance:** Experimental analysis showed that increasing the number of convolutional layers improved feature learning capability and classification accuracy. Additionally, the ReLU activation function provided better performance compared to other activation functions due to improved training efficiency and faster convergence. These findings helped identify optimal CNN configurations for agricultural image analysis.
- **Successful implementation of ANFIS for multi-level quality grading:** A fuzzy logic-based Adaptive Neuro-Fuzzy Inference System (ANFIS) was developed to classify fruits into five quality grades: very good, good, average, poor, and very poor. ANFIS effectively handled uncertainty and variability in agricultural data, providing accurate grading based on extracted physiological and thermal features. This demonstrated the strength of neuro-fuzzy systems in agricultural quality assessment.
- **Superior performance of ANFIS for maturity assessment compared to other AI models:** In guava maturity classification, ANFIS outperformed neural network models and generative AI tools. While neural networks showed good performance, ANFIS provided more accurate and consistent maturity classification due to its ability to incorporate rule-based reasoning and handle uncertainty. Generative AI models showed potential but required further tuning for reliable application.
- **Development of a comprehensive multi-phase grading framework:** The thesis successfully implemented a complete grading system consisting of species classification,

defect detection, shape grading, size grading, ripeness grading, and quality grading. The integration of these stages enabled comprehensive quality evaluation within a unified framework. The results demonstrated that overall grading performance depends on the effectiveness of individual grading modules and their coordinated integration.

- **Establishment of AI-based imaging systems as a practical solution for agro-industry:** The research confirmed that automated AI-based quality assessment systems can significantly improve grading accuracy, reduce human error, minimize post-harvest losses, and enhance operational efficiency. The proposed system provides a scalable, reliable, and practical solution for agricultural industries, supporting automated sorting, grading, and quality monitoring while contributing to improved food quality control and supply chain optimization.