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Fruit Grade

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Abstract: Maintaining consistent fruit quality evaluation and establishing efficient market connectivity are major challenges in the modern agricultural supply chain. Traditional fruit grading methods rely heavily on manual inspection, which can lead to inconsistent results, human error, and inaccurate pricing. Such limitations often cause financial losses for farmers and vendors while also affecting the reliability of quality standards in the market.

The proposed **SmartFruit — AI-powered Fruit Quality Analysis & Vendor Connect Platform** introduces an intelligent solution that utilizes Artificial Intelligence (AI) and Machine Learning (ML) techniques to automate fruit quality assessment. The system analyzes fruit images captured through a mobile or web-based application and classifies them into predefined quality categories such as Grade A, Grade B, and Grade C. Using image processing and deep learning models, the platform evaluates visual attributes including color consistency, ripeness level, surface texture, and visible defects to determine the overall quality of fruits.

In addition to automated grading, the platform integrates a vendor connectivity module that helps farmers identify nearby buyers or vendors, compare potential offers, and maintain digital records of their transactions. The application also provides user-friendly features such as text-based results, optional voice feedback, and historical analysis tracking to improve accessibility and usability.

By combining automated fruit grading with digital market connectivity, the SmartFruit platform enhances transparency in quality evaluation, reduces dependence on manual inspection, and supports efficient decision-making within the agricultural ecosystem. The system ultimately contributes to minimizing post-harvest losses and strengthening the direct connection between farmers and market stakeholders.

Keywords: Artificial Intelligence (AI), Machine Learning, Fruit Quality Classification, Computer Vision, Image Processing, Smart Agriculture Systems, Vendor Connectivity Platform, AI-Based Fruit Grading, Agricultural Supply Chain Management.

INTRODUCTION

Agriculture plays a vital role in supplying fresh fruits to markets and consumers. However, maintaining consistent fruit quality evaluation and ensuring effective connections between farmers and buyers remain major challenges in the agricultural supply chain. Traditionally, fruit grading is performed manually by visually examining characteristics such as color, size, ripeness, and external defects. Although this method is widely used, it often leads to inconsistent results, subjective judgments, and human errors. As a result, farmers may experience unfair pricing, reduced profits, and increased post-harvest losses.

With the growing demand for high-quality fruits in urban markets and export industries, reliable and standardized fruit grading has become increasingly important. At the same time, many small-scale farmers and vendors face difficulties in reaching trustworthy buyers, comparing market prices, and maintaining transparent transaction records. The absence of digital and intelligent tools limits their ability to make informed selling decisions and reduces overall supply chain efficiency.

To overcome these issues, the **SmartFruit — AI-powered Fruit Quality Analysis & Vendor Connect Platform** proposes an intelligent system that uses Artificial Intelligence (AI) and Machine Learning (ML) technologies to automate fruit quality assessment. The platform captures fruit images through a mobile or web-based application and processes them using image processing and deep learning techniques. Based on visual characteristics such as color uniformity, texture patterns, ripeness indicators, and surface defects, the trained model automatically classifies fruits into predefined quality grades including Grade A, Grade B, and Grade C.

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In addition to automated grading, the SmartFruit platform includes a vendor connectivity feature that helps farmers identify nearby buyers or vendors, compare available offers, and maintain a digital record of their transactions. The application also supports both text-based and voice-based output to ensure accessibility for users with different levels of technical knowledge or literacy.

The overall system architecture integrates a user-friendly front-end interface with a secure backend server and a trained machine learning model. The backend processes captured images, extracts important visual features, and applies predictive algorithms to determine fruit quality in real time. The results are presented through an interactive dashboard that displays grading outcomes, analysis history, and vendor recommendations.

By combining AI-driven fruit grading with digital vendor connectivity, SmartFruit offers a scalable and efficient solution for modern agriculture. The system improves quality standardization, reduces manual inspection errors, minimizes post-harvest losses, and enhances transparency in the farmer-to-market supply chain.

RESEARCH OBJECTIVES

I. To design and develop an AI-driven system capable of performing real-time fruit quality assessment by analyzing fruit images and categorizing them into multiple quality grades.
II. To implement a machine learning framework that examines visual characteristics such as color distribution, texture patterns, ripeness indicators, and visible defects to enable accurate automated fruit grading.
III. To incorporate a vendor connectivity module that assists farmers in locating nearby buyers, comparing market prices, and maintaining transparent digital transaction records.
IV. To establish a secure and scalable centralized platform that stores fruit analysis data, user information, and vendor details to support reliable system operation and historical data tracking.
V. To develop a user-friendly interface that provides clear grading results through both text and optional voice output, ensuring

RESEARCH BACKGROUND

The development of the SmartFruit system is motivated by the increasing need for technological innovation in modern agriculture and supply chain management. Fruit quality grading is an important factor that determines the market price, export standards, and overall consumer satisfaction. In many traditional markets, fruit grading is still performed manually by visual inspection. Such methods are often subjective and may lead to inconsistent results because the evaluation depends on human judgment.

Recent advancements in Artificial Intelligence (AI), Machine Learning (ML), and Computer Vision technologies have opened new possibilities for automating agricultural processes. Image-based classification systems are now capable of analyzing complex visual patterns and identifying subtle variations in fruit appearance, including color distribution, texture irregularities, and surface defects. These capabilities make AI-based systems more reliable and efficient compared to conventional manual grading methods.

Another major challenge in agriculture is the lack of direct connectivity between farmers and reliable buyers. Farmers often depend on intermediaries, which may reduce profit margins and limit pricing transparency. Digital platforms and vendor connectivity solutions have been introduced to address these problems by enabling farmers to access market information and connect with buyers more easily.

SmartFruit combines both of these concepts into a unified platform. By integrating AI-powered fruit quality detection with vendor connectivity features, the system helps farmers evaluate fruit quality and simultaneously identify suitable buyers. This research demonstrates how intelligent technologies can improve efficiency in agricultural operations, reduce wastage, and support fair and transparent pricing mechanisms.

LITERATURE REVIEW

Recent research in smart agriculture has highlighted the potential of Artificial Intelligence and Computer Vision technologies for improving agricultural productivity and quality monitoring.

● 2020 | CNN-Based Fruit Quality Classification
Several studies demonstrated that Convolutional Neural Networks (CNNs) can effectively analyze fruit images and

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classify them based on visual characteristics such as color distribution, texture, and visible defects. These systems achieved high accuracy in automated fruit grading tasks.

● 2021 | Machine Learning Applications in Smart Farming

Research in this area showed that machine learning technologies can significantly improve agricultural efficiency by enabling predictive analysis, crop monitoring, and automated decision support systems.

● 2022 | Computer Vision for Fruit Defect Detection

Studies focusing on computer vision techniques reported that image processing algorithms are capable of detecting fruit surface defects, bruises, and ripeness levels more consistently than manual inspection methods.

● 2022 | AI-Based Agricultural Decision Support Systems

Researchers emphasized that integrating AI-powered analytics with intuitive dashboards helps farmers and vendors make informed decisions related to crop quality, pricing, and distribution.

● 2023 | Digital Platforms for Farmer–Vendor Connectivity

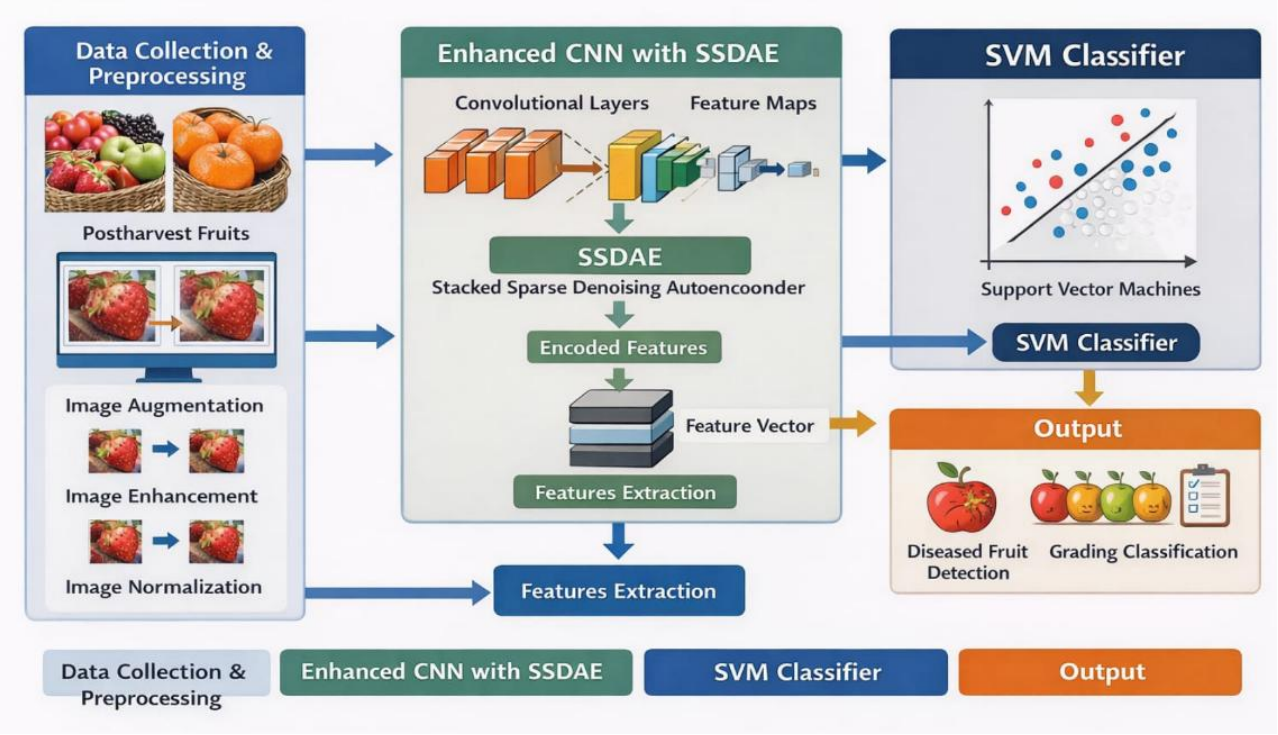

Fig. 1 System architecture.

SYSTEM ARCHITECTURE

The architecture of the SmartFruit — AI-powered Fruit Quality Analysis & Vendor Connect Platform is designed as a layered and scalable framework that enables automated fruit grading, secure data management, and efficient market connectivity. The system integrates image acquisition, machine learning analysis, centralized storage, and result visualization to support real-time fruit quality evaluation and informed decision-making in the agricultural supply chain.

6. User Interface Layer

This layer serves as the primary interaction point for farmers, vendors, and other users. Through a mobile or web-based application, users can capture or upload images of fruits using their device camera. The interface provides an easy-to-use dashboard where users can view fruit grading results, access vendor suggestions, and listen to optional voice feedback. Input validation mechanisms ensure that uploaded images meet required format and quality standards before further processing.

2. Backend Processing Layer

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The backend server handles the core application logic and communication between different components of the system. When a fruit image is uploaded, the backend performs preprocessing tasks such as resizing the image, normalizing pixel values, reducing noise, and extracting relevant visual features. This layer ensures secure data transmission and reliable coordination between the user interface, machine learning engine, and database.

3. Machine Learning Prediction Engine

This component represents the intelligent core of the SmartFruit system. A trained Convolutional Neural Network (CNN) model analyzes the processed fruit images and evaluates visual attributes including color distribution, surface texture, ripeness indicators, and visible defects. Based on these extracted features, the model classifies the fruit into predefined quality grades such as Grade A, Grade B, or Grade C. The system is designed to support multiple fruit types and can be expanded to analyze up to twenty different fruits.

4. Database Layer

All fruit analysis results and related information are stored in a centralized database. This includes fruit grading outcomes, user information, vendor details, and historical analysis records. Maintaining this structured data allows users to track quality trends over time and supports further model training and analytical insights.

5. Visualization and Vendor Recommendation Layer

This layer presents the classification results in a clear and accessible format through the user dashboard. The system displays the predicted fruit grade along with confidence scores and provides optional voice output to enhance accessibility. Additionally, the platform recommends nearby vendors or buyers based on location data and allows users to compare offers and maintain digital transaction records.

6. Learning and Update Layer

To ensure continuous improvement, the system stores newly analyzed fruit images and corresponding classification results. These data samples can later be used to retrain the machine learning model, improving its accuracy and enabling adaptation to new fruit varieties, seasonal variations, and changing agricultural conditions.

PROCESS FLOW

The operational workflow of the SmartFruit system follows several sequential steps:
The user captures or uploads a fruit image using the mobile or web application.

The system validates the image format and quality.
The validated image is transmitted to the backend server.
The backend performs image preprocessing and feature extraction.
The processed image is analyzed by the machine learning model.
The model predicts the fruit quality grade (A, B, or C).
The result is stored securely in the database.
The user dashboard displays the grading result along with vendor recommendations and transaction options.

ALGORITHM USED

The SmartFruit platform utilizes advanced techniques from Computer Vision, Machine Learning, and Deep Learning to perform automated fruit quality classification. Instead of relying on manual inspection, the system analyzes visual patterns in fruit images to determine their quality objectively and consistently.

1. Data Preprocessing

Before training the model, the fruit image dataset undergoes several preprocessing operations to improve model performance. These steps include resizing images to a standard resolution, normalizing pixel values, and applying data augmentation techniques such as rotation, flipping, and brightness adjustments. Images that are excessively blurred or noisy are removed to maintain dataset quality.

2. Deep Learning Model

The primary model used for fruit quality detection is a Convolutional Neural Network (CNN). CNNs are widely used for image classification tasks because they automatically learn hierarchical visual features from input images. In the SmartFruit system, the CNN analyzes fruit characteristics such as color consistency, surface texture, ripeness patterns, and visible defects.

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3. Classification and Probability Estimation

The trained CNN model generates probability scores for each fruit quality category (Grade A, Grade B, and Grade C). The category with the highest probability value is selected as the final classification result. This probability-based approach helps maintain transparency in the grading process and allows users to understand the confidence level of predictions.

4. Vendor Recommendation Logic

After fruit grading is completed, the system provides vendor suggestions based on several parameters including geographic location, vendor ratings, and price comparisons. This feature helps farmers identify suitable buyers for their produce and improves market accessibility.

5. Continuous Learning Mechanism

To maintain long-term system accuracy, newly analyzed fruit images and grading feedback are stored for future model updates. Periodic retraining of the CNN model allows the system to adapt to seasonal changes, regional fruit variations, and new dataset samples.

By combining image preprocessing, CNN-based classification, probability-driven decision mechanisms, and vendor recommendation logic, the SmartFruit system offers a reliable and intelligent framework for automated fruit grading and agricultural market connectivity. This approach improves grading accuracy, reduces manual effort, and enhances transparency within the agricultural supply chain.

In the SmartFruit system, the confidence of fruit quality classification is determined using probability values generated by the trained Convolutional Neural Network (CNN) model. Rather than relying on textual evaluation, the system analyzes visual characteristics extracted directly from the fruit image to estimate the likelihood of each quality category.

The confidence score for each fruit grade is calculated using the predicted probability of the fruit belonging to that specific class.

Score(Grade) = P(Grade | Image)

Where:

P(Grade | Image) represents the probability predicted by the CNN model that the given fruit image belongs to a particular quality grade such as Grade A, Grade B, or Grade C.

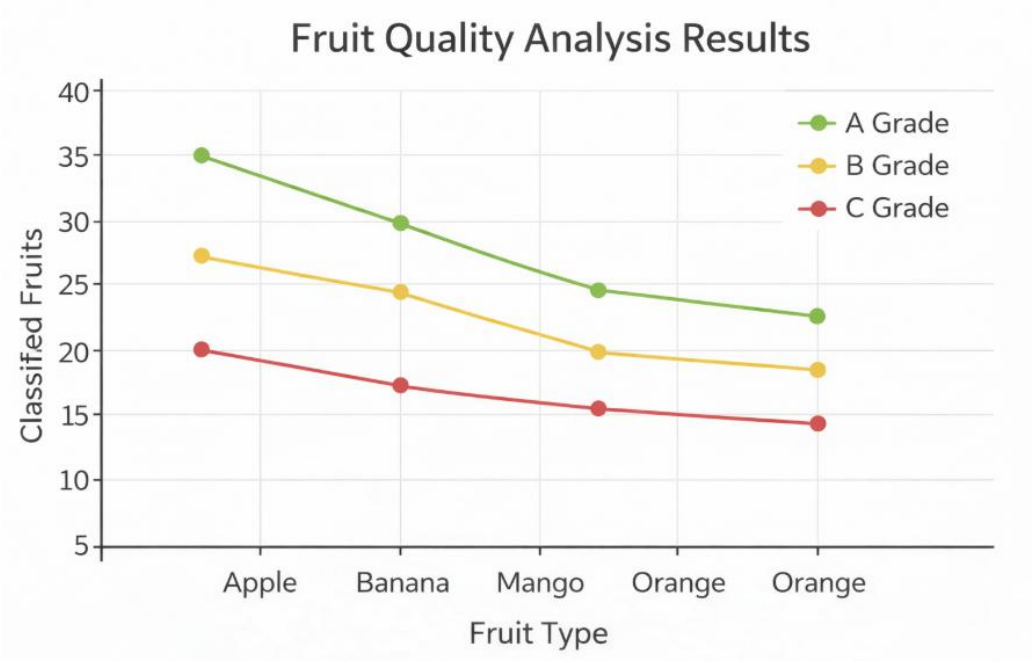

Fig. 3 Website-wise Consent Classification Results.

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The deep learning model examines multiple visual attributes of the fruit image, including color consistency, surface texture patterns, ripeness indicators, and the presence of visible defects. Based on these extracted features, the model assigns probability values to each grade category.

The final fruit grade is selected using a maximum probability decision rule:

Final Grade = argmax (P(A), P(B), P(C))

This means that the fruit is assigned to the category with the highest predicted probability score.
For instance:
• Fruits with uniform color, fresh appearance, and minimal surface defects are more likely to receive a high probability for **Grade A**.
• Fruits with slight variations in texture or moderate ripeness are typically classified as **Grade B**.
• Fruits showing visible damage, over-ripeness, or surface defects are more likely to be categorized as **Grade C**.

This probability-based grading approach allows the SmartFruit system to provide consistent and objective fruit quality evaluation. The calculated confidence score is also displayed to users so that they can understand the reliability of the prediction.

Furthermore, the predicted fruit grade plays an important role in the vendor recommendation module. Fruits classified as higher quality grades can be suggested to premium buyers or export markets, while lower-grade fruits may be directed toward processing industries or local markets. This intelligent combination of grading and recommendation helps farmers make better selling decisions and contributes to reducing post-harvest losses within the agricultural supply chain.

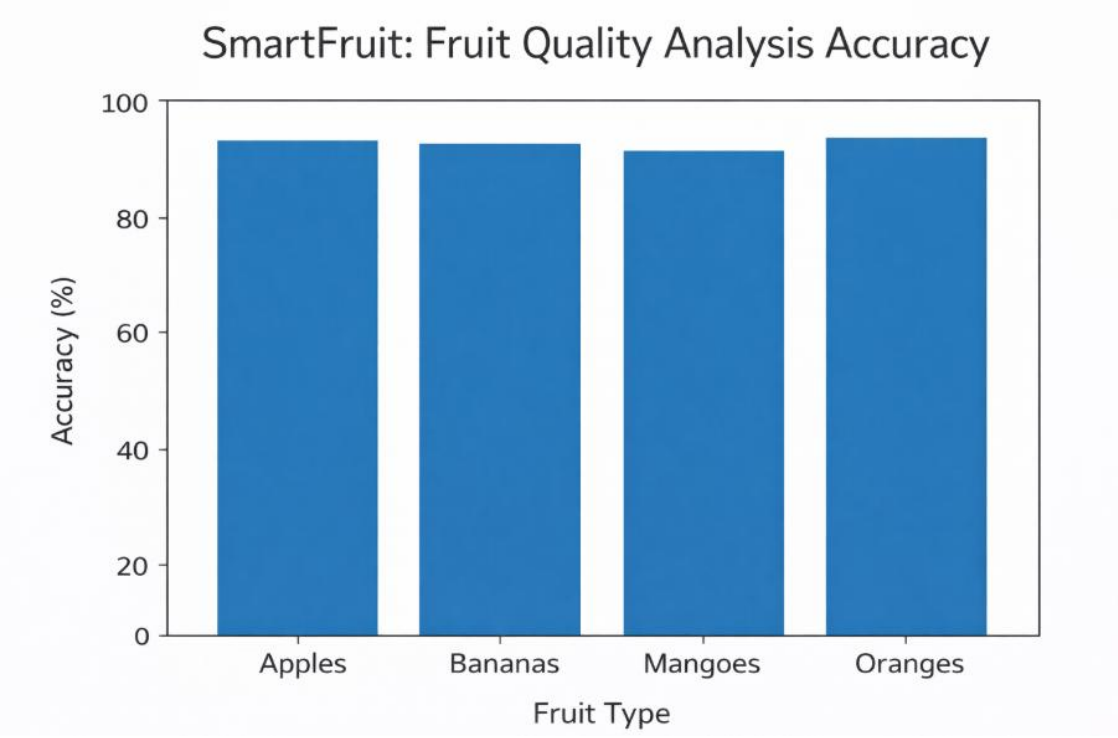

Fig.5 Classification Accuracy of Consent Categories

The SmartFruit system utilizes machine learning–based image classification techniques to automatically evaluate fruit quality and categorize fruits into predefined grades such as Grade A (High Quality), Grade B (Medium Quality), and Grade C (Low Quality). This automated grading approach replaces traditional manual inspection methods with a structured and data-driven process, enabling farmers and vendors to assess the actual market value of fruits more accurately.

Experimental evaluation indicates that the fruit classification module performs reliably across different fruit varieties such as apples, bananas, mangoes, and oranges. Even when variations occur in fruit size, lighting conditions, texture

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patterns, or ripeness levels, the trained Convolutional Neural Network (CNN) model successfully identifies important visual features and differentiates between multiple quality categories. This demonstrates the robustness and adaptability of the AI-based grading system when applied in real agricultural environments.

Accurate fruit quality classification also supports several additional system functionalities. These include intelligent price estimation, vendor recommendation, inventory monitoring, and quality trend analysis. By organizing fruit grading information in a structured digital format, the system improves price transparency, reduces errors associated with manual inspection, and assists both farmers and buyers in making well-informed decisions.

The experimental results suggest that machine learning–driven fruit grading can serve as an effective and scalable solution for modern agricultural supply chain management. The SmartFruit platform enhances grading accuracy, strengthens the direct connection between farmers and market participants, reduces post-harvest losses, and encourages fair and transparent trade through the use of intelligent digital technologies.

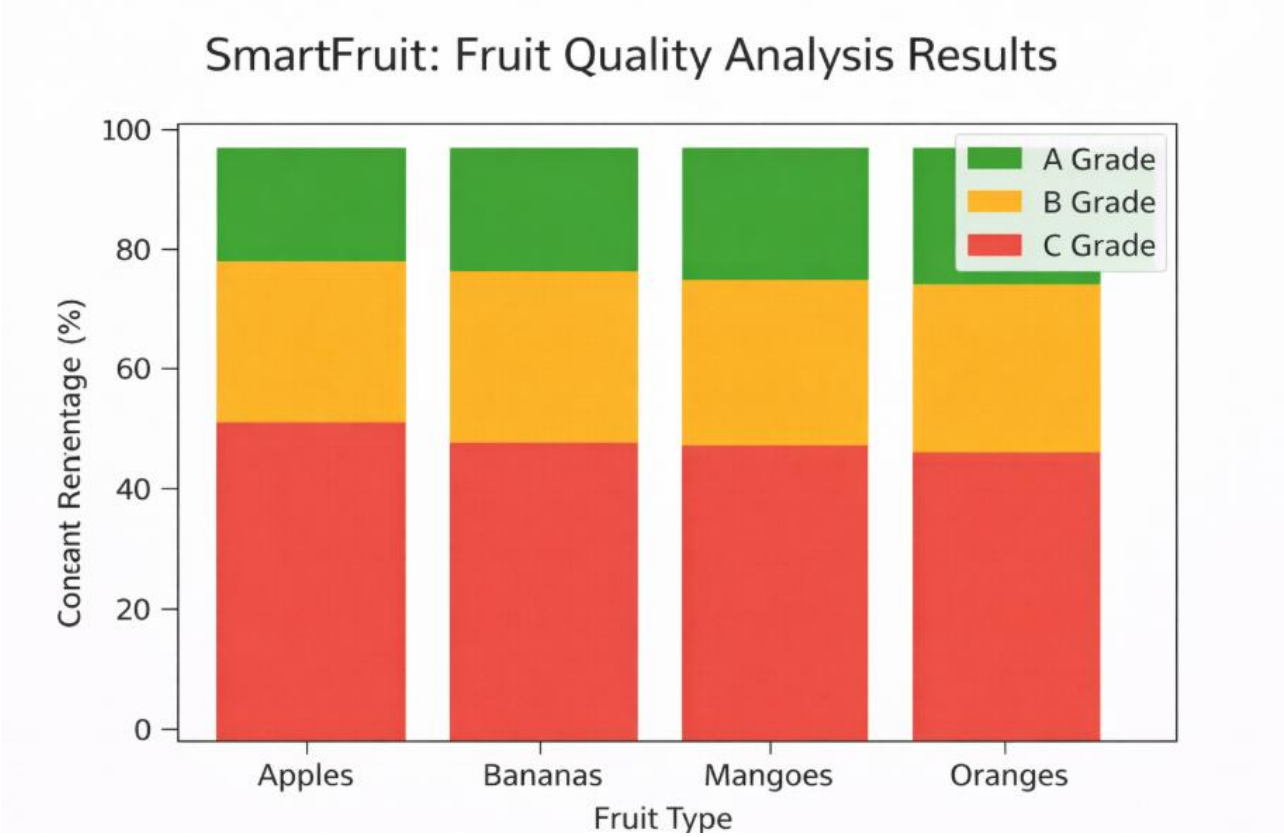

Fig.6 Website-wise Distribution of Consent Types

IMPLEMENTATION

The SmartFruit platform is implemented using a combination of real-time image processing techniques, deep learning models, secure web technologies, and a scalable backend infrastructure. The system is designed with a modular architecture that ensures efficient fruit quality analysis and reliable vendor connectivity.

The main components of the implementation include:
- Image Capture Module
- Backend Processing Server
- AI-Based Classification Engine
- Database Management System
- User Dashboard and Vendor Recommendation Module

The mobile or web application acts as the client interface where users capture fruit images using their device camera or upload images from their device storage. These images are then securely transmitted to the backend server for further processing.

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The backend system performs preprocessing operations on the received images and coordinates communication between the machine learning engine, database, and user interface. The trained AI model evaluates the fruit image and generates the predicted quality grade along with a confidence score. The result is stored in the system database and presented to users through an interactive dashboard.

Client Deployment (Mobile / Web Application Layer)
Users access the SmartFruit platform through a lightweight mobile or web application designed for ease of use. The application provides the following functionalities:
• Capturing fruit images using the device camera
• Uploading images from the gallery
• Displaying real-time fruit grading results
• Providing optional voice-based feedback for accessibility
This interface ensures a smooth and user-friendly experience for farmers and vendors.

Image Capture and Feature Extraction
During the image acquisition process, the system collects important information related to each fruit sample, including:
• Fruit image data
• Fruit type (if selected manually or detected automatically)
• Timestamp of analysis
• User identification details
• Optional location data for vendor matching
Image preprocessing operations include resizing images, normalizing pixel values, reducing noise, and applying augmentation techniques during model training.

AI and Machine Learning-Based Analysis
The backend integrates a deep learning framework responsible for performing fruit classification tasks. This component includes:
• Image preprocessing and preparation
• Feature extraction using Convolutional Neural Networks (CNN)
• Softmax-based classification into Grade A, Grade B, or Grade C
• Generation of prediction confidence scores
The model is trained using labeled fruit image datasets and learns to recognize visual features such as color consistency, texture variations, ripeness indicators, and surface defects.

Secure Authentication and Access Control
To ensure secure data management, the SmartFruit platform implements authentication and authorization mechanisms including:
• User login through email or Google authentication
• JWT-based session management
• Secure API communication through HTTPS
• Role-based access control for farmers, vendors, and administrators

Fruit Management and Vendor Recommendation
After classification, fruit analysis results are stored in a centralized database and displayed through the dashboard interface. Users can:
• Review fruit grading history
• View prediction confidence scores
• Compare offers from nearby vendors
• Maintain digital transaction records
• Monitor fruit quality trends over time
The vendor recommendation module matches fruit grade with market demand, vendor ratings, and geographical proximity, helping farmers connect with suitable buyers.

Tools Used
Programming Languages
• Python (AI and Machine Learning Model)
• JavaScript / TypeScript
• Dart (for Flutter-based application)

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Frontend Technologies
• Flutter or React.js
• HTML and CSS
• REST API communication using Axios
Backend Technologies
• Node.js, Flask, or FastAPI
• RESTful API architecture
• JWT-based authentication
AI and Deep Learning Frameworks
• TensorFlow / Keras / PyTorch
• OpenCV for image processing
• Convolutional Neural Network architecture
Database Systems
• MySQL or PostgreSQL
• Firebase (optional real-time database)
Deployment and Testing Tools
• Docker for containerized deployment
• Postman for API testing
• Android Studio or Visual Studio Code for development

Hardware and Software Requirements
Client Side
• Operating System: Android, Windows, or macOS
• Device: Smartphone or Personal Computer
• Minimum Memory Requirement: 2–4 GB RAM
Server Side
• Operating System: Linux (Ubuntu) or Windows Server
• Hardware Requirement: 8–16 GB RAM
• GPU (optional) for training deep learning models
• SSD storage for faster data processing

Experimental Environment
Training Phase
• Collection of labeled fruit image datasets
• Training of CNN-based classification model
• Evaluation using metrics such as accuracy, precision, and recall
Testing Phase
• Deployment of the trained model in a controlled testing environment
• Testing across multiple fruit categories
• Measurement of classification accuracy and system response time
Monitoring and Evaluation
• Tracking overall grading accuracy
• Evaluating efficiency of vendor recommendation
• Measuring reduction in manual grading errors
• Assessing improvements in pricing transparency and supply chain efficiency

RESULTS AND ANALYSIS

The SmartFruit platform improves efficiency and reliability in fruit quality assessment and vendor connectivity by utilizing Artificial Intelligence and Deep Learning techniques. The trained CNN model analyzes fruit images and classifies them into quality grades with high accuracy, reducing reliance on manual inspection methods.

Experimental testing across multiple fruit varieties such as apples, bananas, mangoes, and oranges demonstrates consistent classification performance. The model successfully identifies important visual features including color distribution, texture patterns, ripeness indicators, and surface defects even under varying lighting conditions or fruit sizes.

The probability-based confidence scores generated by the model provide transparency in the grading process and help users understand the reliability of the predicted results.

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The centralized dashboard enables users to:
• View fruit grading history
• Monitor quality trends over time
• Compare vendor offers according to fruit grade
• Maintain digital transaction records

By organizing fruit analysis data in a clear and structured format, the SmartFruit system supports farmers in making better selling decisions while enabling vendors to evaluate product quality quickly.

Overall, the results demonstrate that SmartFruit provides a scalable and practical solution for automated fruit grading and agricultural supply chain improvement. The integration of AI-based fruit classification with vendor connectivity helps reduce post-harvest losses, improve pricing transparency, and strengthen the connection between farmers and market participants.

The SmartFruit dashboard also allows users to review and manage fruit analysis records at any time. Farmers and vendors can recheck previously analyzed fruits, compare grading results, and make informed decisions regarding pricing and distribution without repeated manual inspection.

Additionally, the system supports exporting fruit analysis reports in formats such as PDF or CSV. These digital records can be used for inventory tracking, pricing discussions, compliance documentation, and business analytics, further enhancing transparency and data-driven decision-making in agricultural operations.

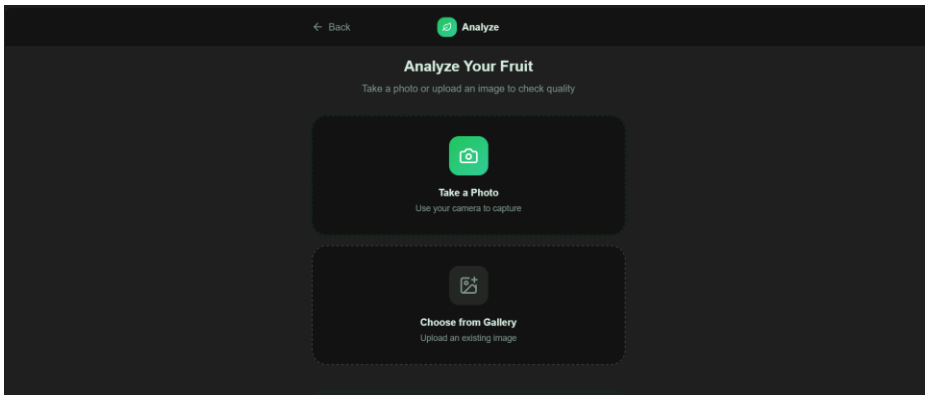

Fig. 6 Real time Accepted Consents

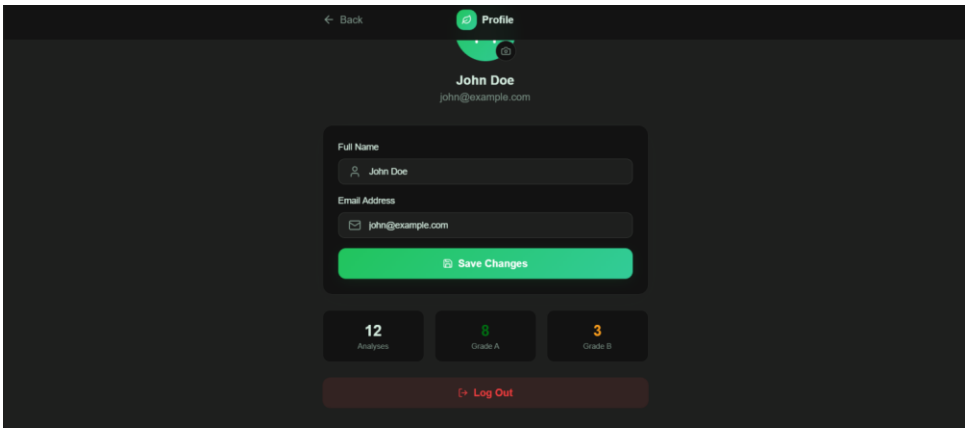

Fig. 7 Consent Details.

This fruit analysis record indicates that a user has evaluated a fruit sample using the SmartFruit platform through the application dashboard. The analysis was conducted at a specific date and time, and the system generated a quality classification along with a confidence score using the trained Convolutional Neural Network (CNN) model. Each analysis session is associated with a unique user session ID, which ensures secure tracking and traceability of fruit analysis records within the system.

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The uploaded fruit image is processed in real time by the machine learning engine. Based on visual characteristics such as color consistency, ripeness level, and surface condition, the system determines the fruit quality grade, which may be categorized as Grade A, Grade B, or Grade C. The analysis results are stored in the system database together with relevant metadata such as fruit type, timestamp, user ID, and optional location information used for vendor recommendations.

The SmartFruit system focuses on storing fruit quality information rather than sensitive personal user data. This approach ensures user privacy while supporting agricultural decision-making through structured digital records. By maintaining these records, farmers and vendors can review previous grading outcomes, monitor quality trends, and compare vendor offers without repeatedly performing manual inspection.

Fig. 8 Fruit Quality Analysis Update
This figure illustrates the updated fruit grading status displayed within the SmartFruit dashboard. The interface presents the predicted fruit grade, the confidence percentage generated by the CNN model, and recommended vendors for potential market connections. Real-time updates allow users to quickly understand the quality of their produce and maintain accurate digital records for pricing decisions, inventory tracking, and business analysis.

CONCLUSION

The SmartFruit — AI-powered Fruit Quality Analysis & Vendor Connect Platform demonstrates the effective application of Artificial Intelligence and Machine Learning technologies in improving fruit quality evaluation and agricultural market connectivity. By utilizing image processing and deep learning techniques, the system automatically analyzes fruit images and classifies them into quality grades such as Grade A, Grade B, and Grade C. This automated grading mechanism significantly reduces the limitations of manual inspection and ensures consistent and objective fruit quality assessment.

The integration of vendor connectivity within the platform further enhances its usefulness by enabling farmers to identify nearby buyers, compare available market offers, and maintain digital transaction records. This functionality strengthens the connection between farmers and vendors, improves transparency in pricing, and reduces dependency on intermediaries.

Experimental observations show that the trained CNN model can reliably detect visual indicators such as color consistency, ripeness levels, and surface defects across different fruit varieties. Additionally, the system maintains structured digital records of fruit analysis, allowing users to track grading history and monitor quality trends over time.
Overall, the SmartFruit platform provides a scalable and intelligent solution for automated fruit grading and agricultural supply chain improvement. By combining AI-driven quality detection with vendor connectivity, the system helps reduce post-harvest losses, improve pricing transparency, and support better decision-making for farmers and agricultural stakeholders.

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