International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 01 | Jan - 2026 SJIF Rating: 8.586 ISSN: 2582-3930

AI Powered Hyper Spectral Seed Analysis Device

Manoj Bhandari[1], Dr. Malatesh S H[2], Milan Bhandari[3], MOHD Irfan[4], Niranjan Sah[5]

[1]Manoj Bhandari, Dept . of CSE,&M S Engineering College,Bengaluru [2]Dr.Malatesh S H, HOD. Of CSE M S Engineering College,Bengaluru [3]Milan Bhandari, Dept . of CSE,&M S Engineering College,Bengaluru
[4]MOHD Irfan, Dept . of CSE,&M S Engineering College,Bengaluru
[5]Niranjan Sah, Dept . of CSE,&M S Engineering College,Bengaluru

---***---

Abstract—In modern agriculture, ensuring high seed quality is essential for maximizing crop yield, maintaining food security, and reducing post-harvest losses. Traditional seed quality assessment methods are largely manual, time-consuming, and prone to human error. This project presents the design and development of an AI Powered Hyperspectral Seed Analysis Device that enables automated, real-time classification and grading of seeds using computer vision, deep learning, and gas-sensing technologies. The system integrates a camera-based imaging module with MQ-3 and MQ-6 gas sensors connected to a microcontroller. Seed images are processed using a YOLO-based deep learning model to detect defects and classify seeds into quality grades, while the gas sensors monitor chemical emissions to identify spoilage or contamination. The combined visual and environmental analysis provides a non- destructive, scalable, and accurate method for seed quality evaluation. The proposed solution is cost-effective, portable, and suitable for applications in agriculture, seed production, and quality certification industries.

Keywords: Hyperspectral Imaging, Seed Quality Analysis, Deep Learning, YOLO, Gas Sensors, MQ-3, MQ-6, Arduino, Agriculture Automation, Computer Vision.

I. INTRODUCTION

High-quality seeds are the foundation of successful agriculture, directly influencing crop yield, food security, and overall farming sustainability. Poor seed quality results in low germination rates, weak plant growth, and increased vulnerability to diseases, which ultimately affects farmers' productivity and income. Traditionally, seed quality evaluation is performed through manual inspection and laboratory testing, which are time-consuming, subjective, and difficult to scale for large agricultural operations. These limitations create a strong need for automated, accurate, and fast methods of seed quality assessment.

With recent advancements in artificial intelligence, computer vision and embedded systems, automated seed analysis has become both practical and efficient. Imaging technologies, including hyperspectral and high-resolution cameras, enable the capture of detailed information related to seed color, texture, shape, and surface defects. Deep learning algorithms are capable of learning complex visual patterns from such data, allowing accurate classification and grading of seeds without physical damage.

This technological progress opens new possibilities for non-destructive, real-time quality monitoring in modern agriculture. In addition to visual defects, seed quality is also affected by environmental factors such as moisture, chemical exposure, and spoilage during storage. These issues often remain undetected until visible deterioration occurs, leading to losses in seed viability. Integrating gas sensors into the monitoring system allows early detection of harmful chemical emissions and potential contamination. By continuously observing both physical and environmental conditions, a more reliable and comprehensive assessment of seed quality can be achieved.

This paper presents an AI Powered Hyperspectral Seed Analysis Device that combines deep learning– based live seeds processing with gas sensing technology for automated seed grading. The system employs a YOLOv5 model to classify seeds based on visual characteristics, while MQ-3 and MQ-6 gas sensors monitor the surrounding environment for chemical emissions.

II. METHODOLOGY

1. Data Acquisition

Seed are captured in real time using a webcam or hyperspectral camera to obtain visual information about size, color, and surface characteristics. At the same time, gas concentration around the seeds is continuously monitored using MQ-3 and MQ-6 sensors. Both image and sensor data are transmitted to the processing unit simultaneously. This ensures continuous observation of seed quality and surrounding environmental conditions.

2. Preprocessing and Feature Extraction

Captured seeds are preprocessed using OpenCV techniques such as noise reduction, resizing, and normalization for better clarity. Important features including color, texture, shape, and surface defects are extracted from the images. Sensor signals are converted into digital form using an ADC for accurate measurement. These values are compared with baseline thresholds to detect abnormal conditions.

3. AI-Based Seed Classification

A YOLOv5 deep learning model is trained using annotated seed image datasets for accurate detection and grading. During real- time operation, the model analyzes incoming frames and identifies individual seeds. Each seed is classified based on learned visual features. The system grades seeds into categories such as Grade A, B, C or Good and Bad automatically.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 01 | Jan - 2026 SJIF Rating: 8.586 ISSN: 2582-3930

4. Gas Detection and Alert System

The MQ-3 and MQ-6 sensors continuously monitor harmful gases and chemical emissions around the seeds. Sensor readings are compared with predefined safety thresholds to detect contamination or spoilage. When gas concentration exceeds the safe limit, the system generates a warning. A "Chemical Detected" message is displayed on the LCD and the data is logged for monitoring.

5. System Integration

Gas sensors are interfaced with a microcontroller such as Arduino or ESP32, while the camera module is connected through a USB interface. The LCD is used to display real-time results and alert messages. A Python- based backend synchronizes AI model outputs with sensor readings. All data is presented through a web interface for real-time visualization and reporting.

III. Requirements

The proposed AI Powered Hyperspectral Seed Analysis Device requires clearly defined functional and non- functional requirements to ensure accurate seed quality assessment, reliable gas detection, real-time processing, and user-friendly operation.

A. Functional Requirements:

Seed Image Acquisition

The system shall capture real-time original seeds using a webcam or hyperspectral imaging camera for quality analysis.

Seed Quality Analysis and Classification

The system shall analyze seed using deep learning models (YOLOv5) and classify seeds into quality grades such as Excellent, Average, and Worst based on visual attributes like color, texture, size, and defects.

Defect Detection and Object Recognition

The system shall detect damaged, discolored, or foreign elements within seed clusters using AI-based object detection.

Gas Detection and Environmental Monitoring

The system shall continuously monitor surrounding air using MQ-3, MQ-6 (and related) gas sensors to detect chemical odors, spoilage indicators, or harmful emissions.

Threshold-Based Alert Mechanism

The system shall trigger visual alerts on the LCD display when gas concentration exceeds predefined safe baseline values.

Data Processing and Visualization

The system shall process sensor data and AI model outputs in real time and display seed grades, detected defects, and gas alerts through the user interface.

Data Logging and Reporting

The system shall store sensor readings and classification results for future analysis, reporting, and model improvement

Non-Functional Requirements Performance

The system shall perform real-time image processing and gas detection with minimal latency for immediate decision-making.

Scalability

The system shall support future expansion such as additional sensors, cloud integration, and advanced AI models.

Usability

The system shall provide a clear and user-friendly interface with easy-to-understand visual outputs and alerts on the LCD and web interface.

Reliability

The device shall operate continuously with consistent performance and handle sensor noise, environmental variations, and lighting conditions gracefully.

Security and Privacy

All collected data shall be protected from unauthorized access and securely handled during processing and storage.

B. Use Case

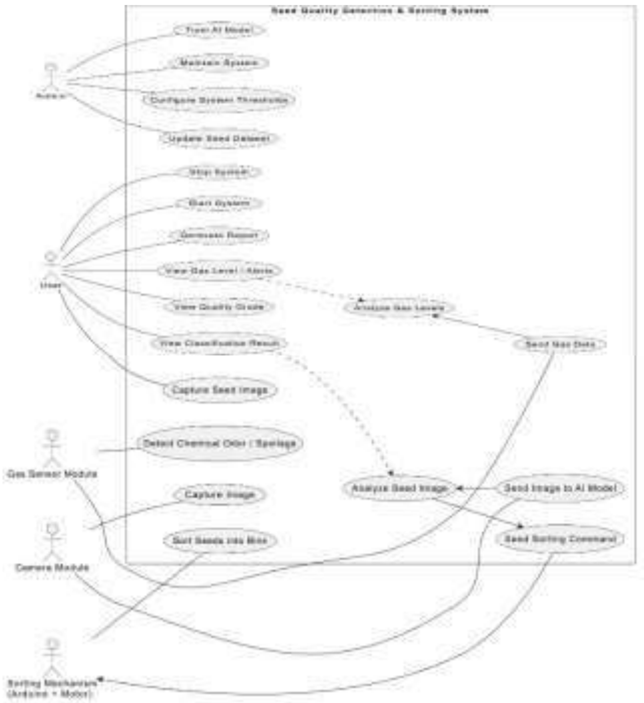

Fig 1. Use case diagram of AI Power Hyperspectral Seed Analysis Device

C. System Architecture

1. Input and Sensing Layer

This layer collects raw data from the physical environment using a hyperspectral camera and gas sensors (MQ-3, MQ-6). The camera captures seed images for quality analysis, while gas sensors detect chemical odor and spoilage. Sensor outputs are converted using an ADC before further processing.

2. Processing and Control Layer

The microcontroller (Arduino/ESP32) acts as the central control unit of the system. It receives digitized sensor data, performs basic filtering and threshold checks, and manages communication between hardware and software modules. It also controls alert mechanisms in real time.

3. AI and Data Analysis Layer

Seed are processed using Python-based computer vision and deep learning models such as YOLOv5. The system classifies and grades seeds into quality categories while analyzing gas sensor data against predefined thresholds.

4. Output and Visualization Layer

Processed results are displayed through a web interface and an LCD module. Seed grades, detected defects, and gas alerts are shown in real time using HTML, CSS, JavaScript, and Flask/FastAPI. This enables quick user awareness of quality and environmental conditions.

5. Data Storage and Reporting Layer
All classification results and sensor readings are stored in a database or cloud platform for future reference. The stored data supports report generation, performance analysis, and system improvement. It also enables remote monitoring through IoT-based dashboards.

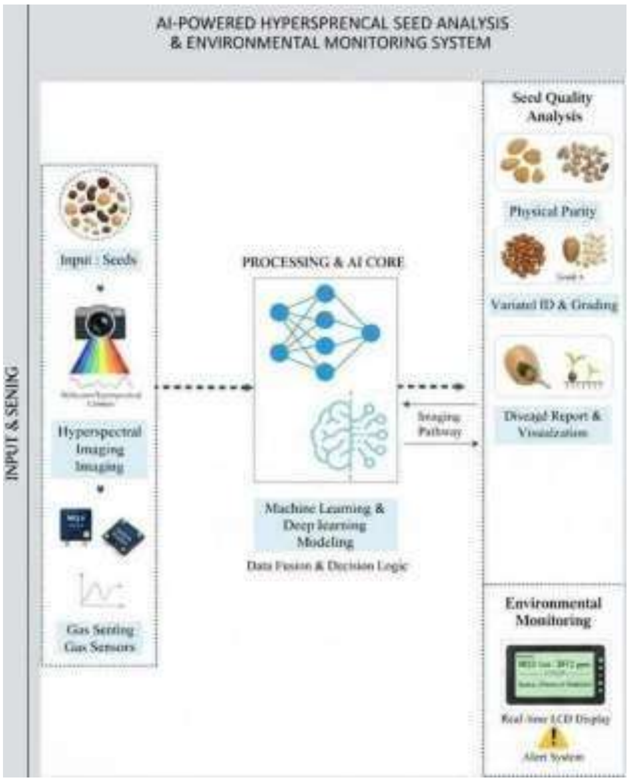

Fig 2. System Architecture

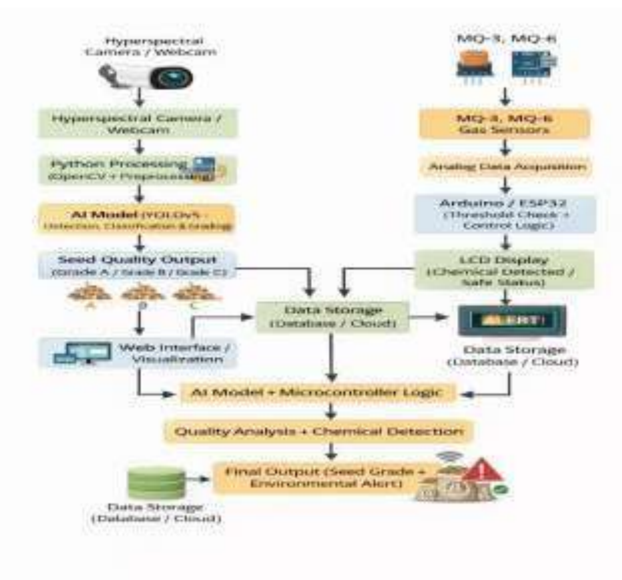

Fig 3. Workflow

D. Workflow

The workflow of the proposed system begins with acquiring seed using a hyperspectral camera or webcam. Simultaneously, MQ-3 and MQ-6 gas sensors monitor the surrounding environment for

chemical odor and spoilage. The analog gas sensor outputs are converted into digital form and transmitted to the microcontroller. The microcontroller applies threshold checks and control logic to determine safe or unsafe conditions. Captured seed images are pre-processed using Python and OpenCV for noise removal and enhancement.

The processed images are forwarded to the AI model (YOLOv5) for detection, classification, and grading. Based on the model output, seeds are categorized into quality grades such as Grade A, Grade B, and Grade C. The classification results are displayed on a web interface for real-time visualization.

In parallel, environmental status is shown on an LCD display connected to the microcontroller. Both image analysis results and sensor data are stored in a database or cloud platform. The AI model and microcontroller outputs are combined for quality analysis and chemical detection.

Finally, the outputs from the AI model and the microcontroller are integrated through a combined decision layer that performs quality analysis and chemical detection. This layer generates the final system output in the form of seed grade along with environmental alert status, enabling accurate quality assessment and early detection of potential spoilage or hazardous conditions. The complete workflow ensures real-time monitoring, reliable decision-making, and data- driven reporting for agricultural quality control.

E. Circuit Diagram

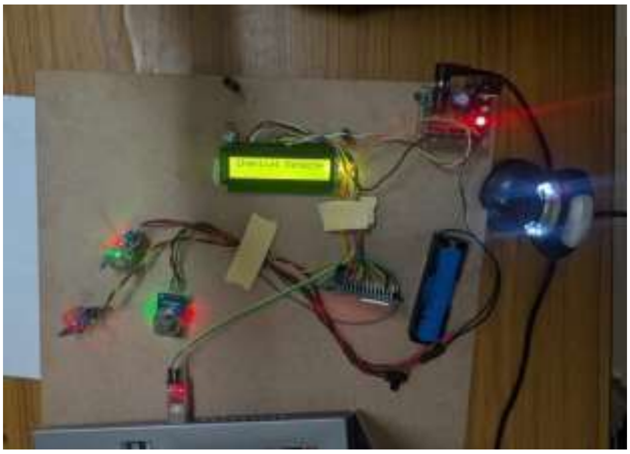

Fig 4.1 circuit diagram

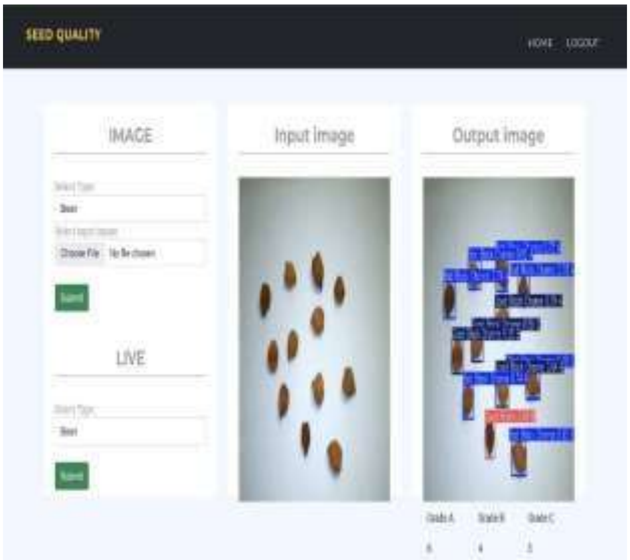

Fig 4.2 Input Method

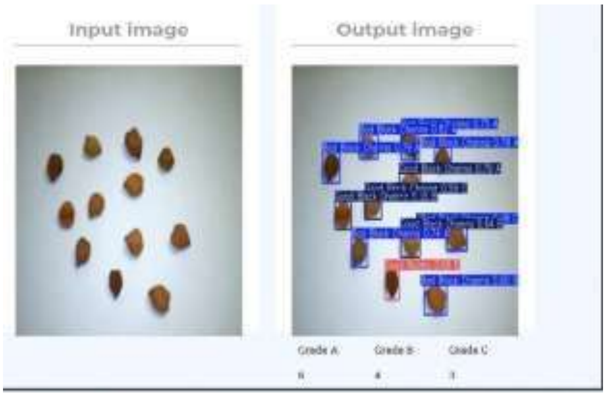

Fig 4.2 Seed Quality Detection

IV. Future Scope

Advanced Hyperspectral Sensors
High-resolution hyperspectral cameras can be used to detect internal defects, moisture levels, and chemical composition of seeds with greater accuracy.

Multi-Crop Seed Analysis
The AI model can be trained for multiple crops such as rice, wheat, maize, pulses, oilseeds, and vegetables by expanding the dataset.

Cloud-Based Data Management
Seed quality data can be stored on cloud platforms for large-scale monitoring, reporting, and long-term analysis.

Mobile Application Interface
A farmer-friendly mobile app can provide real-time results, alerts, and recommendations based on AI analysis.

Automated Sorting and Grading
The system can be integrated with conveyor belts and robotic arms to automatically separate seeds into quality grades (A/B/C).

Enhanced Environmental Monitoring
Additional sensors for temperature, humidity, CO_2, ammonia, and VOCs can be added for better storage and spoilage detection.

Edge AI and Embedded Processing
Lightweight AI models can be deployed directly on embedded hardware for faster processing without continuous internet connectivity.

Predictive Analytics for Crop Yield
Historical seed data can be used to predict germination rate, crop yield, and disease probability before plantation.

Industrial and Warehouse Integration
The system can be adapted for seed processing units, cold storage, and warehouses for continuous quality monitoring.

Commercialization and Government Adoption
With optimization and cost reduction, the device can be commercialized for seed testing laboratories, agro- industries, and government seed certification agencies.
Future improvements may include the integration of deep learning models for automatic feature extraction directly from raw ECG signals, enhanced sensor fusion (combining ac celerometer, SpO2, and respiratory data), and cloud-based analytics for longitudinal monitoring.

Conclusion:

In The AI Powered Hyper Spectral Seed Analysis Device presents an innovative approach to seed quality assessment by combining artificial intelligence, imaging technology, and gas sensing modules. The system enables real-time, non-destructive analysis of seeds by detecting defects, grading quality, and identifying possible environmental or chemical abnormalities. This integrated framework reduces dependency on manual inspection while ensuring faster and more consistent evaluation.

By automating the seed grading process, the proposed system improves accuracy, minimizes human error, and enhances operational efficiency for farmers, seed producers, and agricultural industries. The inclusion of AI-based image processing and sensor- based monitoring ensures reliable detection of low-quality or contaminated seeds before they are used for cultivation. As a result, the project contributes to improved crop yield, reduced agricultural losses, and better resource utilization.

REFERENCE:

1. C. Simões, F. S. Osório, P. Carvalho, and L. Pádua, *"A deep learning approach for seed classification and quality evaluation,"* Computers and Electronics in Agriculture, 2018.

2. H. B. Maghsoudi, M. Sabzi, and M. Minaei, *"Seed classification by machine learning and color texture analysis,"* Computers and Electronics in Agriculture, 2017.

3. D. Sehgal, A. Singh, and R. Kaur, *"Seed quality assessment by image analysis: A review,"* Computers and Electronics in Agriculture, 2017.

4. M. A. S. Rezvani, H. Maghsoudi, and M. Minaei, *"An intelligent system for seed quality classification using deep convolutional neural network,"* Computers and Electronics in Agriculture, 2020.

5. M. A. S. Rezvani, H. Maghsoudi, and M. Minaei, *"Seed quality evaluation and classification using machine learning techniques,"* Computers and Electronics in Agriculture, 2017.

6. Dr. Malatesh S.H., S.Kattimani, Pallabavi, V. A. P., and D. M. G., "Intruder Detection and Protection System," International Journal of Innovative Research in Technology (IJIRT), vol. 11, no. 12, p. 6287, May 2025, ISSN: 2349-6002.