

A Real-Time Embedded Solution for Intelligent Seed Segregation with Web Visibility

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Abstract- This paper presents the development of an intelligent seed segregation system integrated with environmental monitoring and web-based visibility for smart agriculture applications. The proposed system utilizes an ESP8266 microcontroller to collect real-time temperature and humidity data through sensors and automatically separate good and defective seeds using a servo-driven mechanism. A rover-based platform enables mobility and remote operation through a web interface, allowing farmers to monitor system status and environmental conditions from any location. The system reduces manual labor, minimizes human error, and improves seed quality management through automation and data-driven decision-making. The prototype demonstrates reliable performance, low power consumption, and efficient wireless communication under real-time conditions. This work highlights the potential of embedded IoT technologies in enhancing agricultural productivity and supports the transition toward precision farming practices.

Index Terms — Intelligent Seed Segregation, Smart Agriculture, Embedded System, ESP8266, Environmental Monitoring, Servo Motor, IoT, Web Interface Control, Real-Time Monitoring, Rover Automation, Automated Seed Sorting, Precision Farming.

I. INTRODUCTION

Agriculture plays a crucial role in ensuring food security and economic stability, particularly in developing countries. Seed quality is one of the primary factors influencing crop yield, germination rate, and overall agricultural productivity. Traditional seed segregation methods mainly depend on manual inspection and human judgment, which are time-consuming, labor intensive, and prone to errors. Inconsistent seed selection can result in poor crop growth and reduced yield, highlighting the need for

automated and reliable seed quality management systems.

Recent advancements in embedded systems, Internet of Things (IoT), and automation technologies have enabled the development of smart agriculture solutions. Environmental parameters such as temperature and humidity significantly affect seed storage conditions and quality. By integrating sensors with embedded controllers, real-time monitoring and data-driven decision-making can be achieved, improving the efficiency and accuracy of agricultural operations. Automated systems can reduce human intervention while ensuring consistent performance under varying environmental conditions.

Modern smart farming approaches emphasize remote monitoring and control through web-based platforms. Wireless communication technologies allow farmers to access real-time information about agricultural processes from any location. This capability is especially beneficial in large-scale farming environments where continuous manual supervision is difficult. The integration of automation with web visibility enhances operational flexibility and enables timely decision-making to prevent seed deterioration

Despite these advancements, many existing seed sorting systems either rely on expensive machine vision techniques or lack real-time monitoring and remote accessibility. Additionally, most solutions are not designed for field deployment due to high cost and complexity.

This work presents the development of an intelligent seed segregation system with web visibility for smart agriculture applications. The proposed system uses an ESP8266-based embedded controller to collect

environmental data and automatically separate good and defective seeds using a servo-driven mechanism. A rover-based platform provides mobility, while a web interface enables real-time monitoring and remote control. By integrating sensing, automation, and connectivity into a single solution, the system improves seed quality management and supports precision farming practices.

Furthermore, the adoption of intelligent automation in agriculture contributes to sustainable farming by optimizing resource utilization and minimizing post-harvest losses. Automated seed segregation ensures that only high-quality seeds are selected for cultivation, which directly improves crop health and productivity. By eliminating defective seeds at the initial stage, farmers can reduce wastage, improve germination rates, and enhance overall yield. Such technology-driven solutions support the transition from traditional farming methods to precision agriculture.

In addition, the proposed system is designed to be affordable and scalable, making it suitable for small and medium-scale farmers who may not have access to expensive agricultural technologies. The use of low-power embedded hardware and wireless communication ensures efficient operation even in rural areas with limited infrastructure. This approach demonstrates that smart agriculture solutions can be both economically viable and technologically advanced, encouraging wider adoption of automation in the agricultural sector. Moreover, the integration of IoT technology with embedded systems enables continuous monitoring and intelligent control of agricultural processes. Real-time data collection and analysis allow farmers to make informed decisions regarding seed selection and storage conditions. Automated segregation reduces manual labor and improves operational efficiency. The web-based interface provides remote accessibility, ensuring convenient monitoring from any location.

II. LITERATURE REVIEW

Recent advancements in smart agriculture and embedded electronics have significantly influenced the development of automated seed quality management systems. Several researchers have

explored machine vision techniques, IoT-based environmental monitoring, and embedded automation platforms, which form the foundation for the proposed work. These technologies enable real-time data collection, intelligent decision-making, and automated segregation processes that improve efficiency and accuracy compared to traditional manual methods.

Feng et al. presented a machine vision-based seed sorting system using deep learning techniques for real-time classification. Their research focused on identifying seed defects and variations through image processing, achieving high sorting accuracy compared to manual inspection. The study demonstrated that automated classification can significantly improve efficiency and consistency in seed quality assessment. Che et al. developed a real-time detection system for identifying varieties and defects in moving seeds using an improved object detection algorithm. Their approach enabled continuous monitoring and inline sorting in dynamic conditions, making it suitable for industrial-scale seed processing. The results showed enhanced detection speed and reliability, highlighting the potential of intelligent automation in agricultural applications.

Cujbescu et al. evaluated optical sorting techniques for separating maize seeds intended for sowing. Their research emphasized the effectiveness of optical sensors in distinguishing seed quality based on color and size characteristics. However, the study also identified limitations such as the unintended rejection of some good seeds, indicating the need for more precise and adaptive sorting mechanisms.

Regina and Venkatalakshmi proposed an IoT-based seed sorting system integrating sensors, embedded controllers, and a web application for remote monitoring. The system demonstrated real-time environmental monitoring and automated segregation, reducing manual effort and improving operational efficiency. This work highlights the importance of combining embedded automation with connectivity to develop practical smart agriculture solutions.

III. DESCRIPTION OF EXISTING SYSTEM

Existing seed segregation methods in agriculture primarily rely on manual inspection and traditional

mechanical techniques. Farmers typically separate seeds based on visual observation of size, color, and physical condition, which requires significant time and labor. This process is prone to human error and inconsistency, often leading to poor seed selection and reduced crop productivity.

Some modern systems use mechanical sorting machines that separate seeds based on weight, size, or airflow. Although these methods improve speed compared to manual sorting, they lack intelligence and adaptability to varying environmental conditions. These machines cannot accurately detect internal defects or quality variations that are not visible externally.

Machine vision-based sorting systems have also been developed to automate seed classification using image processing techniques. While these systems provide higher accuracy, they require expensive cameras, powerful processing units, and controlled lighting conditions. Such requirements make them unsuitable for small-scale farmers and field deployment.

Additionally, many existing systems lack real-time monitoring and remote accessibility features. Farmers cannot track seed quality parameters or system performance from remote locations. The absence of integrated environmental sensing and web-based control limits the effectiveness of these systems in modern smart agriculture applications.

Therefore, existing seed segregation solutions are either labor-intensive, costly, or limited in functionality. These limitations highlight the need for a cost-effective, intelligent, and remotely accessible system capable of automated seed segregation and real-time monitoring, which is addressed by the proposed work.

Furthermore, existing seed segregation practices often lack integration with environmental monitoring systems that influence seed quality during storage and handling. Factors such as temperature and humidity are critical for maintaining seed viability, yet most conventional methods do not provide real-time tracking of these parameters. Without proper monitoring, seeds may deteriorate before planting, resulting in reduced germination rates and agricultural

losses. This limitation emphasizes the necessity for an intelligent system that combines automated segregation with continuous environmental monitoring and data visibility.

III. CHALLENGES IN THE EXISTING SYSTEM

Existing seed segregation systems face several technical and operational challenges that limit their effectiveness in modern agriculture. One major issue is the heavy dependence on manual labor for seed inspection and sorting, which is time-consuming and prone to human error. Inconsistent segregation can result in poor seed quality selection, directly affecting crop yield and productivity.

Another challenge is the lack of intelligent decision-making in traditional mechanical sorting machines. These systems rely only on physical characteristics such as size and weight, without considering environmental factors that influence seed quality. As a result, they cannot accurately distinguish between viable and defective seeds under varying conditions.

Machine vision-based solutions, although accurate, require expensive hardware, high computational power, and controlled environments for reliable operation. This makes them difficult to deploy in rural areas and small-scale farming applications. Additionally, the absence of real-time monitoring and remote accessibility reduces the usability of such systems in large agricultural fields.

Furthermore, most existing systems do not integrate environmental sensing, automation, mobility, and connectivity into a single platform. The lack of a comprehensive solution limits their scalability and adaptability to smart agriculture practices. These challenges highlight the need for a cost-effective, intelligent, and remotely accessible seed segregation system capable of operating efficiently in real-world agricultural environments.

In addition, many existing systems are not designed with cost-effectiveness and scalability in mind, making them inaccessible to small and medium-scale farmers. High installation costs, complex maintenance requirements, and energy consumption issues further

restrict their practical adoption in rural areas. The absence of user-friendly interfaces and remote monitoring capabilities also limits the ability of farmers to efficiently manage seed quality operations. These constraints emphasize the need for a simple, affordable, and energy-efficient solution that can be easily deployed in diverse agricultural environments.

IV. PROPOSED SYSTEM

The proposed system is an intelligent seed segregation solution designed to improve seed quality management through automation, environmental monitoring, and remote accessibility. The system utilizes an ESP8266 microcontroller as the central processing unit to collect real-time data from temperature and humidity sensors. Based on predefined threshold values, the controller automatically determines seed quality conditions and activates a servo-driven mechanism to separate good and defective seeds.

A rover-based platform is incorporated to provide mobility, allowing the system to operate across different locations within agricultural fields. The rover movement is controlled through a web interface, enabling users to remotely navigate and manage the segregation process. This mobility enhances operational flexibility and reduces the need for manual handling.

The proposed system also integrates wireless communication to transmit sensor data to a web application for real-time monitoring. The web interface displays environmental conditions, system status, and segregation analytics, providing complete visibility to users. Remote control commands can be sent through the interface to operate the rover and segregation mechanism, ensuring efficient management from any location.

A. BLOCK DIAGRAM

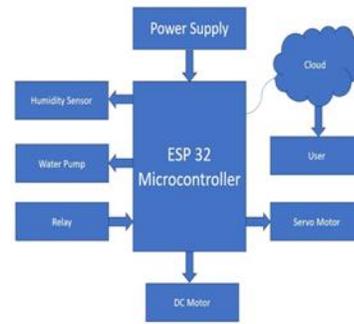


Fig1. Block Diagram

The block diagram illustrates the overall architecture of the proposed intelligent seed segregation system with web visibility. The system is powered by a regulated DC supply, which provides stable power to all electronic components. The ESP8266 microcontroller acts as the central processing unit, coordinating data collection, decision-making, and control operations.

A motor driver module controls the rover movement, enabling the system to navigate across different locations. Wireless communication is established through the built-in Wi-Fi module of the ESP8266, allowing data transmission to a web server. The web interface displays sensor readings, system status, and segregation results while also enabling remote control commands.

B. FLOW CHART

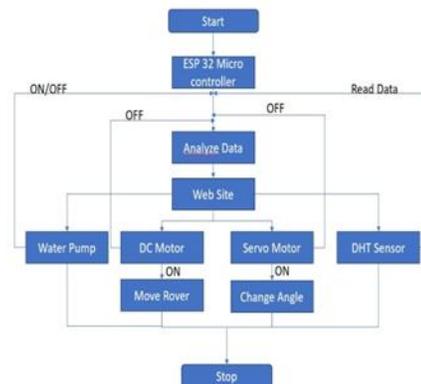


Fig2. Flow Chart

The flowchart represents the operational sequence of the proposed intelligent seed segregation system. The

process begins with system initialization, where the ESP8266 controller, environmental sensors, and communication modules are configured. Required program libraries and network settings are loaded to enable real-time operation. The sensors continuously monitor temperature and humidity conditions affecting seed quality, and the collected data is processed by the controller. Based on predefined threshold values, the system determines whether the seeds meet quality requirements and activates the servo mechanism for segregation. The rover movement and system status are controlled through the web interface, allowing remote monitoring and operation. The process continues in a loop for continuous segregation until the stop condition is triggered.

C. HARDWARE IMPLEMENTATION

The hardware of the proposed system includes an ESP8266 microcontroller, temperature and humidity sensors, a servo motor for seed segregation, a motor driver for rover movement, and a wireless communication module integrated within the controller. The ESP8266 acts as the central processing unit, controlling data acquisition, decision-making, and actuation. Sensors are connected to monitor environmental conditions in real time, while the servo motor performs the separation of good and defective seeds based on controller commands. All components are mounted on a rover platform to enable mobility across different areas. The motor driver controls the movement of the rover, allowing navigation through remote commands sent via the web interface. Stable connections between modules are maintained using appropriate wiring and connectors, ensuring reliable operation. The system operates on a regulated DC power supply to provide safe and efficient performance in agricultural environments.

Hardware Components:

i. Environmental Sensors:

Temperature and humidity sensors are used to monitor environmental conditions affecting seed quality. The sensors provide real-time data to the controller for analysis and decision-making.

ii. ESP8266 Microcontroller:

The ESP8266 is a low-cost Wi-Fi-enabled microcontroller that serves as the main controller. It processes sensor data, controls the segregation mechanism, and manages communication with the web interface.

iii. Servo Motor:

A servo motor is used to operate the mechanical segregation unit. It automatically separates good and defective seeds based on the controller's decision.

iv. Motor Driver Module:

The motor driver controls the movement of the rover platform, enabling navigation across different locations through remote commands.

v. Rover Platform and Power Supply:

The rover structure supports all hardware components and allows mobility. A regulated DC power supply ensures stable and safe operation of the entire system.



Fig3. Hardware Components

D. WORKING OF PROPOSED SYSTEM

The working of the proposed intelligent seed segregation system begins with powering the ESP8266-based embedded controller, which initializes the environmental sensors and communication modules. Temperature and humidity sensors continuously monitor conditions affecting seed quality, and the collected data is processed in real time to determine suitability based on predefined thresholds. When seeds are introduced into the system, the controller activates a servo-driven mechanism to automatically separate good and defective seeds, ensuring accurate segregation without manual intervention. Simultaneously, the built-in Wi-Fi

module transmits sensor data and system status to a web interface for remote monitoring. Users can also send control commands through the interface to operate the rover movement and segregation process. This integrated operation enables automated, real-time, and remotely accessible seed quality management for smart agriculture applications.

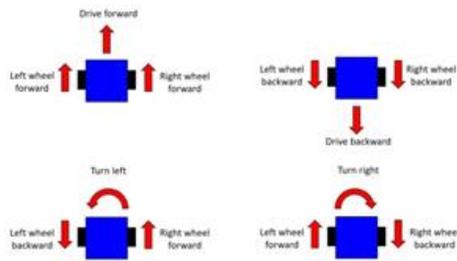


Fig4. Working of Proposed System

V. RESULT AND DISCUSSION

The developed prototype of the intelligent seed segregation system was successfully implemented using an ESP8266 microcontroller integrated with environmental sensors, a servo motor mechanism, and a web-based monitoring interface. The system operated reliably under real-time conditions, demonstrating stable performance without communication failures or excessive power consumption. Temperature and humidity sensors accurately monitored environmental parameters affecting seed quality, enabling data-driven decision-making.

The servo-driven segregation mechanism effectively separated good and defective seeds based on predefined threshold values. The automated process

significantly reduced manual effort and improved consistency compared to traditional sorting methods. The rover movement control functioned smoothly through the web interface, allowing remote navigation and operation across different locations.



Fig.5 Developed Intelligent Seed Segregation Prototype

Wireless communication between the embedded system and the web application remained stable, ensuring real-time data transmission and remote accessibility. The dashboard displayed sensor readings, system status, and segregation analytics clearly, enabling users to monitor operations efficiently. The system maintained low latency during command execution, confirming its suitability for real-time agricultural applications.

The results demonstrate that the proposed system provides a cost-effective, scalable, and energy-efficient solution for intelligent seed segregation. By integrating sensing, automation, mobility, and connectivity, the system enhances seed quality management and supports precision farming practices.

VI. CONCLUSION

The proposed intelligent seed segregation system with web visibility provides an effective solution for improving seed quality management in modern agriculture. By integrating environmental sensing, embedded processing, automated segregation, rover mobility, and remote monitoring into a single platform, the system reduces manual labor and human error while enhancing operational efficiency. The ESP8266-based implementation demonstrates that reliable automation can be achieved using low-cost

and energy-efficient hardware suitable for rural deployment. Real-time monitoring through the web interface enables farmers to make informed decisions and manage operations from any location. Experimental results confirm stable performance, low latency, and accurate segregation under real-time conditions. Overall, the system supports precision farming practices and contributes to sustainable agricultural development by improving productivity and resource utilization. This work highlights the potential of embedded IoT technologies in transforming traditional farming into smart agriculture.

Furthermore, the proposed system demonstrates the practical feasibility of integrating automation and connectivity in agricultural processes using low-cost embedded hardware. The combination of sensing, decision-making, and actuation within a single platform ensures efficient operation while maintaining affordability for farmers. The mobility feature provided by the rover enhances coverage across different areas of the field, making the system adaptable to varying agricultural requirements.

Future enhancements can include the integration of machine vision techniques for advanced seed classification, cloud-based data analytics for long-term monitoring, and mobile application support for improved accessibility. Incorporating renewable energy sources such as solar power can further enhance sustainability and enable continuous operation in remote locations. These improvements will expand the system's capabilities and support the development of next-generation smart farming solutions.

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