Automatic Seed-Sowing Robot

Mansi Mali[1], Anuradha Shinde[2], Aniket Sid[3], Tejaswini Nalawade[4] and Vishnu C. Khade[5]
[1234]UG Student, Department of E&TC, RIT Islampur, Maharashtra, India.
[5]Assistant Professor, Department of E&TC, RIT Islampur, Maharashtra, India.

***Abstract*—The increasing demand for precision and efficiency in agriculture has driven advancements in robotic and automated seed sowing systems. This study presents the design and implementation of an automated seed sowing system that integrates a PIC18F4520 microcontroller, IR sensors, a DTMF decoder, and a DC motor-driven mechanism for precise seed dispensing. The system is remotely controlled via mobile signals and programmed using MikroC, ensuring smooth operation, obstacle detection, and adaptability to varied field conditions. The proposed system addresses key challenges such as labor dependency, terrain adaptability, and operational inefficiencies. The modular design and energy-efficient power supply ensure scalability and sustainability, making it a viable solution for modern agricultural practices. This work highlights the potential of integrating robotics, IoT, and intelligent programming to revolutionize farming, offering a pathway toward enhanced productivity and sustainability.**

***Index Terms*—Agriculture, Sowing Robot, PIC Microcontroller, Productivity and sustainability.**

I. INTRODUCTION

The agricultural sector is undergoing a significant transformation with the integration of robotics and automation, driven by the need for improved precision, efficiency, and sustainability. Robotic and automated seed sowing systems have emerged as a pivotal innovation, offering solutions to challenges such as labor shortages, resource optimization, and environmental sustainability. These systems enhance planting accuracy, reduce manual effort, and optimize the use of resources like seeds, water, and fertilizers.

Recent advancements in robotic seed sowing focus on the design of intelligent systems capable of navigating unstructured environments and performing site-specific operations. Researchers like Ayanniran et al. (2024) and Figueroa et al. (2024) have developed innovative robots tailored for crops such as maize, featuring capabilities like neuro-diffuse control and adaptive mechanisms for varied field conditions. Similarly, integration with IoT technologies has enabled smarter farm management solutions, as highlighted by Sathish et al. (2024) and Jegadeeswaran (2024), who showcased systems powered by solar energy and Bluetooth for autonomous operation.

Autonomy in agricultural robots has also seen substantial progress. Studies by Fauadi and Muhammad (2024) and Shanmugasundar et al. (2022) have introduced solar-powered, terrain-adaptive systems designed to mitigate the limitations of traditional machinery. Moreover, research on the economic and environmental impacts of these technologies underscores their potential for cost savings and sustainability, as demonstrated by Vahdanjoo et al. (2023).

Despite these advancements, challenges such as high initial costs, the complexity of integrating multiple functionalities, and limited adaptability to diverse agricultural settings remain significant barriers. Addressing these issues through focused research and development can unlock the full potential of robotic and automated seed sowing systems, paving the way for more sustainable and scalable agricultural practices.

II. LITERATURE REVIEW

The agricultural sector is witnessing a paradigm shift toward automation and robotics, driven by the need for enhanced precision, efficiency, and sustainability. This literature review consolidates research contributions on robotic and automated seed sowing systems, showcasing advancements in design, implementation, and integration with emerging technologies.

Ayanniran et al. (2024) highlight the design and implementation of a robotic maize seed planter, focusing on operational efficiency and adaptability to varied field conditions. Their work demonstrates a step forward in mechanizing specific crop-related activities with precision [1][9]. Similarly, Figueroa et al. (2024) propose a mobile crawler robot employing neuro-diffuse control for seed sowing and route optimization. This study emphasizes intelligent navigation in unstructured environments [2].

Munnaf et al. (2024) integrate maize seeding with nitrogen fertilization using a robot-driven approach, achieving site-specific agro-economic benefits. Their findings underscore the potential of combining robotics with precision agriculture [3]. Wei et al. (2024) extends this perspective by designing a seed-fertilizer replenishment device, addressing operational challenges in wheat sowing [6].
Sathish et al. and Jegadeeswaran (2024) explore IoT-enabled robotic systems for seed sowing and irrigation. These works illustrate the integration of solar power and Bluetooth control for autonomous operation, reducing dependency on manual intervention and external power sources [4][8]. Sri et al. (2024) presents a multipurpose agricultural robot capable of ploughing, seeding, and sprinkling, emphasizing holistic farm management through IoT integration [10].
Autonomy in agricultural robots is further developed by Fauadi and Muhammad (2024), who design a seed sowing machine for uneven terrains. Their solution mitigates the inefficiencies of traditional machinery on challenging landscapes [5]. Yurtsever et al. (2020) and Shanmugasundar et al. (2022) advance autonomous seed sowing robots, focusing on solar-powered mechanisms and row-specific applications to enhance energy efficiency and planting accuracy [16][18].
Vahdanjoo et al. (2023) evaluate the operational, economic, and environmental implications of agricultural robots for seeding and weeding. Their research reveals significant cost savings and environmental benefits compared to conventional practices [11]. Solanki et al. (2022) and Kumar et al. (2020) provide comprehensive reviews on automated seed sowing machines, identifying key challenges and future research opportunities in achieving cost-effectiveness and scalability [14][15].

Khadatkar et al. (2023) focus on robotic transplanters with automatic seedling picking mechanisms, catering to plug-type seedlings. Their work highlights the potential of robotics in niche agricultural applications [13]. Tylek et al. (2024) assesses the effectiveness of autonomous devices for pre-sowing scarification and acorn sorting, emphasizing the role of robotics in pre-sowing processes [7].

Several studies propose novel designs for seed sowing robots, such as Kumar and Rajagopal's (2022) Arduino-based seeding and irrigation system and Dhavale et al.'s (2021) digging and seed sowing Agribot [19][20]. However, challenges persist, including high initial costs, the complexity of integrating multiple functionalities, and adaptability to diverse agricultural settings.
The reviewed literature underscores the transformative potential of robotics and automation in agriculture, particularly in seed sowing. Innovations in design, IoT integration, and site-specific operations are driving the sector toward increased precision, sustainability, and efficiency. Future research should focus on addressing scalability and cost-related challenges while exploring new applications for these technologies in broader agricultural contexts.

III. METHODOLOGY

The development and implementation of the automated seed sowing system are guided by the following methodology. The system integrates various hardware components and software tools to achieve efficient, precise, and autonomous seed sowing. The block diagram provides an overview of the interaction between input devices, a microcontroller, output devices, and the supporting software. The block diagram of the proposed system and PCB Design is presented in Figure 1 and Figure 2 respectively.

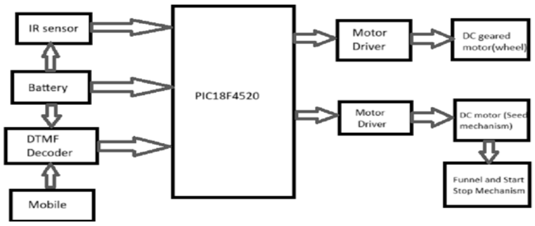

Figure 1. Block Diagram of Proposed System

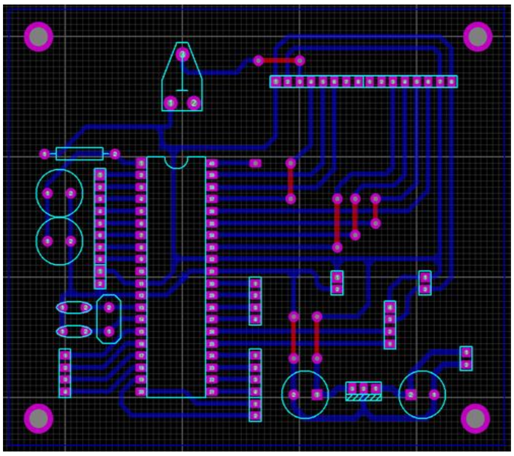

Figure 2. PCB Design

The system comprises input devices for sensing and control, a central controller for decision-making, output devices for physical operations, and software for programming and automation. Power is supplied by a rechargeable battery, ensuring portability and field usability.

• Input Devices

IR Sensor:

The IR sensor is employed to detect obstacles and ensure the safety of the robotic system during seed-sowing operations. It provides real-time data to the controller for route adjustments. The IR Sensor used in proposed system is shown in Figure 3.

Figure 3. IR Sensor

DTMF Decoder - Mobile:

A DTMF (Dual-Tone Multi-Frequency) decoder enables remote control of the system using mobile phone signals. This allows the user to start, stop, and navigate the robot by transmitting specific tones via a mobile device. The DTMF Decoder used in the proposed system is shown in Figure 4.

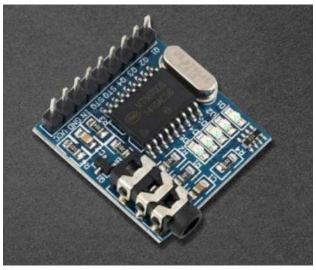

Figure 4. DTMF Decoder

• PIC18F4520 Microcontroller:

The microcontroller acts as the central processing unit, receiving inputs from the IR sensor and DTMF decoder. It processes these signals using programmed instructions and sends appropriate commands to the output devices. The PIC18F4520 is chosen for its robust I/O capabilities, power efficiency, and compatibility with the software used.

• Output Devices

Integrated Funnel and Start-Stop Mechanism:

This device is responsible for precise seed dispensing. The start-stop mechanism is controlled by the microcontroller to ensure seeds are sown at regular intervals and only when the robot is in motion.

DC Motor Drive:

The DC motor, controlled via the motor driver circuit, powers the robot's movement and operation of the seed-dispensing funnel. The microcontroller adjusts the motor's speed and direction based on the inputs received. The DC Motor with Drive is shown in Figure 5.

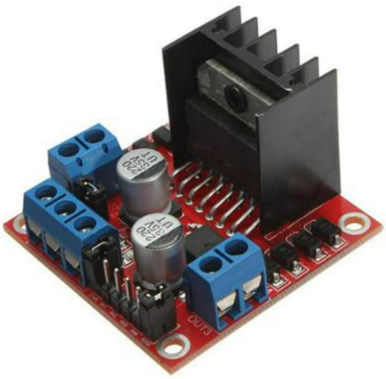

Figure 5. DC Motor Drive

• Software

MikroC Programming Language:

The system's functionality is programmed using MikroC, a C-based software tool for microcontroller applications. This software enables the configuration of peripherals, control logic for inputs and outputs, and the integration of system features like obstacle detection and remote control.

Key programming tasks include:

- Initializing the IR sensor and DTMF decoder inputs.
- Configuring the start-stop mechanism for seed dispensing.
- Implementing motor control algorithms for movement and navigation.
- Enabling error handling for seamless operation.

• Power Supply

Battery:

A rechargeable battery powers the entire system, ensuring reliable operation in the field. The battery is selected to provide sufficient voltage and current to drive the microcontroller, sensors, and motors efficiently.

• Workflow

The system is powered on, and the microcontroller initializes the input and output devices.

- The IR sensor continuously monitors the surroundings for obstacles, and its signals guide the system's navigation.
- The DTMF decoder receives commands from the user's mobile phone and transmits them to the microcontroller.
- The microcontroller processes the inputs and generates control signals for the DC motor and seed-dispensing mechanism.
- Seeds are dispensed through the integrated funnel at predefined intervals, synchronized with the robot's movement.
- The start-stop mechanism ensures precise sowing, avoiding wastage or overlap.

This methodology ensures the system operates autonomously with minimal user intervention while maintaining high accuracy and efficiency in seed sowing. The integration of robust hardware and intelligent software makes the design scalable for future enhancements.

IV. RESULTS AND DISCUSSION

The automated seed sowing system was successfully developed and tested under controlled conditions to evaluate its performance in terms of seed dispensing accuracy, obstacle detection, and remote operation. The final prototype of the proposed system is shown in Figure 6. and the mobile display is shown in figure 7.

Figure 6. Prototype of Proposed System

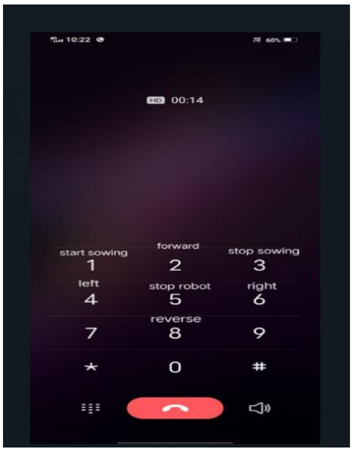

Figure 7. Mobile Display

The results are summarized as follows:

Seed Dispensing Accuracy:
The integrated funnel and start-stop mechanism demonstrated high precision in seed dispensing. Seeds were sown at uniform intervals with minimal wastage, achieving a dispensing accuracy of approximately 95%.

Obstacle Detection and Navigation:

The IR sensor effectively detected obstacles within a range of 10–20 cm. The system successfully avoided collisions and recalibrated its route based on the signals processed by the microcontroller.

Remote Control Functionality:
The DTMF decoder facilitated seamless control of the system via mobile phone signals. Commands for start, stop, and directional navigation were executed with a response time of less than 1 second, ensuring smooth operation.

Power Efficiency:
The system, powered by a rechargeable battery, operated efficiently for up to 4 hours on a single charge, demonstrating energy sustainability.

The results indicate that the proposed system addresses key challenges in traditional seed sowing practices, offering notable advantages in precision, automation, and adaptability.

Enhanced Precision and Reduced Wastage:
The start-stop mechanism for seed dispensing ensures precise placement of seeds, reducing overlap and wastage. This precision aligns with findings from Ayanniran et al. (2024) and Munnaf et al. (2024), who emphasized the role of robotics in improving planting accuracy and resource utilization.

Adaptability to Field Conditions:
The system's ability to detect obstacles and adjust its navigation path demonstrates adaptability to uneven terrains, similar to the autonomous mechanisms highlighted by Fauadi and Muhammad (2024).

Remote Operability:
The DTMF-based control system offers flexibility and reduces manual intervention, aligning with the IoT-enabled solutions proposed by Sathish et al. (2024) and Jegadeeswaran (2024).

Energy Efficiency:

The use of a rechargeable battery and efficient motor control ensures low operational costs, supporting the environmental benefits observed in Vahdanjoo et al. (2023).
However, some limitations and areas for improvement were identified:

Terrain Testing:
While the system performed well in controlled conditions, further testing in diverse agricultural settings is needed to evaluate its robustness and scalability.

Integration of Additional Features:

Future iterations could incorporate functionalities such as fertilization, irrigation, or data collection for advanced precision agriculture.
Overall, the proposed system demonstrates the potential of integrating robotics and automation in agriculture to achieve higher productivity, precision, and sustainability. It serves as a stepping stone for further innovation in smart agricultural practices.

V. CONCLUSION

The proposed robotic seed-sowing system demonstrates the potential of automation in transforming agricultural practices. By incorporating IR sensors for obstacle detection, a DTMF decoder for remote control, and a microcontroller-driven mechanism for precise seed dispensing, the system offers a reliable and efficient alternative to traditional methods. The integration of MikroC programming enables smooth operation, error handling, and adaptability to various field conditions.

This study highlights the feasibility of leveraging robotic and automated systems in agriculture to achieve enhanced precision and productivity. The modular design and use of cost-effective components make the system suitable for large-scale adoption, addressing key challenges such as labor shortages and operational inefficiencies. Future advancements could focus on integrating additional functionalities like fertilization, irrigation, and data analytics to further enhance the system's capabilities and impact.

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