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Design and Development of an Automated Seed Metering Bot for Precision Agriculture

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Abstract: Precision agriculture aims to increase agricultural productivity while reducing resource use and environmental impact. A critical component of this approach is seed metering—the accurate placement of seeds to optimize crop growth and uniformity. Traditional seed metering methods are often labor-intensive and imprecise, leading to inconsistent seed spacing, resource waste, and potential yield reduction. The Automatic Seed Metering Bot addresses these challenges by providing a fully autonomous solution that integrates advanced sensors, GPS, and real-time data processing to ensure precise seed placement across variable field conditions. This bot is designed to adapt to different terrains, soil types, and planting requirements, optimizing seed distribution to enhance crop uniformity and yield potential. Capable of self-adjustment based on real-time field conditions, it requires minimal human intervention, reducing labor costs and allowing for more efficient large- scale farming operations. By integrating with other precision farming technologies, such as aerial drones and soil analysis systems, the bot enables data-driven decision-making and improves planting accuracy. The projected design helps to improve productivity benefits, the Automatic Seed Metering Bot supports sustainable farming practices by minimizing seed waste and optimizing resource use, thus contributing to both economic and environmental goals in agriculture.

Keywords : Automated Seed Sowing, equal spacing, agriculture benifits, sustainable sowing, seeder

I. INTRODUCTION

In the face of rapid population growth and limited arable land, the agricultural sector is increasingly adopting innovative technologies to enhance crop yields, optimize resource use, and reduce environmental impact. Precision agriculture has emerged as a transformative approach, leveraging data and automation to refine every stage of the farming process. Central to this advancement is the need for precision in seed planting—a factor that directly influences crop uniformity, growth rates, and yield outcomes. Traditional seed metering systems, which are often manually operated or rely on basic mechanical systems, can be inconsistent, leading to issues such as seed overcrowding, inefficient spacing, and waste. To address these challenges, the development of an Automatic Seed Metering Bot offers a promising solution. [1]

The Automatic Seed Metering Bot is an autonomous machine designed to precisely meter and place seeds at specified intervals across a field, enhancing planting accuracy and improving crop uniformity. Through advanced sensor technology, GPS, and machine learning algorithms, the bot can adapt its operations based on real-time data from the field, taking into account variables like soil type, moisture levels, and terrain conditions. Unlike traditional systems, which may require manual calibration and are limited in adaptability, this bot is capable of self-adjustment to maintain consistent seed spacing, even in challenging or variable field environments. This adaptability not only maximizes yield potential by ensuring even seed distribution but also reduces resource waste and mitigates the risk of crop overcrowding or underplanting. One of the key advantages of the Automatic Seed Metering Bot is its ability to integrate with other precision farming technologies. By syncing with data from aerial drones, weather forecasting, and soil analysis tools, the bot can make highly informed decisions on the optimal time and method for planting, taking precision agriculture to a new level. [2]

Furthermore, the bot is designed to operate autonomously, requiring minimal human intervention once configured. This automation reduces labor demands, which is particularly valuable in regions facing workforce shortages. Additionally, it decreases operational costs and enables farmers to manage larger plots of land with greater efficiency. The bot's intelligent design incorporates a range of sensors and computational systems that monitor and adjust seed drop rates in real time.

These sensors help the bot maintain ideal spacing based on crop requirements, thereby maximizing the available growing area and minimizing seed wastage. In turn, this level of control contributes to sustainable farming practices, as it optimizes resource use and reduces input costs such as seeds, water, and fertilizers. Over time, farmers can see improvements not only in yield quantity but also in crop quality, as plants benefit from adequate spacing and reduced competition for nutrients. [3]

The evolution of seed sowing technology spans centuries, beginning with simple manual methods and advancing into modern precision agriculture. In ancient times, farmers sowed seeds by hand, a method known as broadcasting. While simple, this technique lacked accuracy, leading to uneven crop growth and significant seed wastage. A major milestone came in 1701 with the invention of the seed drill by Jethro Tull, an English agriculturist. His innovation mechanized the process by placing seeds in evenly spaced rows and covering them with soil. This drastically improved plant spacing, germination rates, and crop yields, laying the foundation for mechanized farming. By the 1800s, animal and steam-powered machines started to replace manual labor. Early seed drills were driven by ground wheels, which mechanically powered the metering system. These systems used fluted rollers or seed cups but still lacked precision for small or irregular seeds. In the mid-1900s, metering discs with precisely drilled holes became popular. These discs ensured each seed was picked up and dropped at uniform intervals. Although driven mechanically, they marked a significant improvement in sowing accuracy. The late 20th century saw the integration of electronics, including servo motors, to rotate the metering disc at controlled speeds. This eliminated dependency on ground wheels and allowed operators to program sowing rates digitally. Modern-day precision sowing machines incorporate GPS modules for path tracking, ultrasonic sensors for obstacle detection, and motor drivers for real-time control of seed placement. These advancements ensure uniform seed spacing, minimal wastage, and optimized field coverage. Such systems are part of precision agriculture, where data and automation are used to increase productivity and sustainability. Today's smart seeders represent the fusion of mechanical engineering, electronics, and digital technology, continually transforming agriculture into a high-efficiency domain.

A. *Current Scenario of Automated Seed Metering Bots*

As of mid-2025, automated seed metering bots have become integral to modern precision agriculture, driven by advancements in robotics, artificial intelligence (AI), and Internet of Things (IoT) technologies. These innovations aim to enhance planting accuracy, optimize resource utilization, and address labor shortages in the agricultural sector. [3]

1) *Key Developments and Trends*

a) Integration of AI and Robotics: Modern seed metering bots are equipped with AI algorithms that analyze real-time data on soil conditions, weather patterns, and crop requirements. This enables precise control over seed placement, depth, and spacing, leading to improved germination rates and crop yields. Robotic systems ensure consistent operation, reducing human error and labor dependency.

b) Market Growth and Investment: The global market for automatic seeding machines and robotics is experiencing significant growth. Factors such as increasing food demand, the need for sustainable farming practices, and technological advancements are driving this expansion. Investments in this sector are fueling innovation and the development of more efficient seeding technologies.

c) Adoption of Autonomous Seeders: Autonomous and semi-autonomous seeders are gaining popularity, especially in large-scale farming operations. These machines can operate with minimal human intervention, navigating fields using GPS and sensor data to plant seeds accurately. This autonomy enhances efficiency and allows for continuous operation, even in challenging conditions.

d) Emphasis on Sustainability: Automated seed metering bots contribute to sustainable agriculture by optimizing input usage. Precise seed placement reduces waste, and the integration with variable-rate technology ensures that seeds are planted only where conditions are optimal. This approach conserves resources and minimizes environmental impact.

e) Challenges and Accessibility**:** Despite the benefits, the high initial cost of automated seeding equipment can be a barrier for small and medium-sized farms. Efforts are underway to develop cost-effective solutions and provide financing options to make this technology more accessible.

2) *Future Outlook*

The trajectory of automated seed metering bots points toward increased integration with comprehensive farm management systems. As technology becomes more affordable and user-friendly, adoption is expected to rise across various scales of farming operations. Continued innovation will likely focus on enhancing interoperability, data analytics capabilities, and adaptability to diverse agricultural environments.

B. System Design and Components

The automated seed metering bot is designed by integrating both mechanical and electronic subsystems to perform precision sowing. The structure supports mobility, accurate seed dispensing, obstacle avoidance, and path control. The overall system is divided into two primary categories: Mechanical Structure and Electronic Components.

1) Mechanical Structure

The mechanical subsystem ensures stable movement and proper handling of the seeds during the sowing process. Key components include:

- Chassis Frame with Wheels: A sturdy chassis made of lightweight metal or polymer materials, designed to carry all components and provide mobility across different terrains. The wheels are mounted to allow smooth forward and turning motion.
- Hopper for Seed Storage: A container positioned on the top of the bot to hold a bulk quantity of seeds. It is designed with a sloped base to ensure continuous feeding of seeds into the metering system.
- Seed Metering Disc: A rotating disc fitted below the hopper with precision-drilled holes of a standard diameter. It ensures one seed is picked and dropped per hole, maintaining uniform seed spacing during sowing.
- Seed Delivery Pipe: A guiding tube that channels the seed from the metering disc directly to the soil. It is aligned to ensure accurate drop positioning.

2) Electronic Components

The electronic subsystem is responsible for automation, control, and sensing. The components used are:

- Arduino Uno Microcontroller: The central controller that processes inputs from sensors and controls all output devices including motors and servos.
- Servo Motor (for Metering Disc): Used to rotate the metering disc at controlled intervals as per programmed logic, ensuring precision in seed dispensing.
- Ultrasonic Sensor (Obstacle Detection): Detects obstacles in the path of the bot and sends feedback to the Arduino to pause or redirect movement.
- DC Motors with Motor Driver: Provides locomotion to the bot. Controlled via motor driver modules (e.g., L298N), enabling forward, backward, and turning motions.
- Power Source (Battery): A rechargeable lithium-ion battery is used to power all electronic components, ensuring portability and uninterrupted operation in the field.

They focuses on the integration of advanced technologies like LiDAR, AI, UAVs, and robotics for managing the spaces between crop rows in vineyards and orchards. These innovations enhance precision, efficiency, and sustainability in agricultural tasks such as mowing, pruning, fertilization, and crop health monitoring. Key findings include LiDAR-enabled canopy mapping, AI-based row detection for improved machine guidance, and autonomous robotic operations that reduce labor dependence. The study concludes that the synergy between AI, LiDAR, and robotics is revolutionizing inter-row management by improving accuracy and yield while reducing manual intervention. [4] Investigate how different flap geometries affect the efficiency of OWSCs used for wave energy harvesting. Through simulation-based analysis, they found that the second flap geometry produced the highest power output (41.52 W) and capture width ratio (52.14%). Wider flaps were less efficient due to resistance, and optimal flap alignment with wave elevation was essential for maximizing energy transfer. The study highlights Geometry 2 as the most efficient design, offering valuable insights for enhancing OWSC performance in renewable energy systems. [5]

They reviews technological advancements in potato planting. The paper emphasizes smart seeding devices integrated with real-time sensing, seed metering, and feedback systems to enhance efficiency and uniformity. Reliable methods like the cup-and-spoon system are supported by sensor fusion technologies that adjust sowing parameters dynamically. Machine vision further enables the detection of missed seeds and allows for AI-driven corrections. The study concludes that sensor-based precision seeding significantly improves accuracy, reduces waste, and offers a sustainable approach to potato cultivation. [6]

Traditional seed sowing techniques, primarily manual broadcasting or simple mechanical drills, face significant limitations in precision, efficiency, and scalability. Manual sowing is labor-intensive and prone to human error, leading to uneven seed distribution, overlapping, or gaps, which adversely affect germination and crop yield. Mechanical seed drills have improved accuracy but often lack adaptability to variable field conditions such as soil fertility differences and obstacles. Moreover, small and medium-scale farmers frequently cannot afford high-end precision farming equipment, which limits their access to modern agricultural technologies.

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There is an urgent need for an affordable, automated solution that not only ensures precise seed metering and placement but also enables autonomous navigation, obstacle avoidance, and real-time adaptability to field conditions. Such a system should reduce dependency on skilled labor, minimize seed wastage, improve crop uniformity, and increase overall farming productivity. With global challenges like food security, rising labor costs, and environmental sustainability, integrating automation into sowing processes can play a crucial role in revolutionizing agriculture, especially in developing regions. [7]

Focussed the challenges faced by small-scale farmers in seed sowing. It reviews conventional and modern techniques and introduces a low-cost, manually-operated seed drill made from recycled materials. The proposed device ensures uniform seed spacing and depth, minimizes wastage, and can be operated by a single person. Additionally, the BBF (Broad Bed Furrow) technique enhances moisture retention and reduces water use by up to 30%, resulting in yield improvements of 5–10%. This innovation promotes affordable precision farming for resource-limited farmers. [8]

The scope of automated seed metering bots in agriculture is rapidly expanding, driven by the need for precision, efficiency, and sustainability in modern farming practices. These bots are not just limited to seed sowing they hold immense potential for multi-functional, intelligent, and integrated agricultural operations [9,10]

The following points highlight the future scope and development possibilities:

- Variable-Rate Seeding: One of the most promising features is the ability to perform variable-rate seeding, where the bot dynamically adjusts the number of seeds planted based on real-time soil fertility data. This ensures that fewer seeds are used in low-yield zones and more in high-potential areas, leading to better resource management and higher productivity.
- Multi-Functionality: Future bots are expected to evolve into multi-purpose agricultural robots. In addition to seed metering, they could be equipped with modules for automated fertilization, soil tilling, weed detection and removal, and even crop health monitoring. This integration would reduce the need for multiple machines and human intervention, saving both time and labor costs. [11,12]
- Remote Monitoring and Control: With advancements in IoT and wireless communication, these bots can be equipped with remote monitoring capabilities. Farmers will be able to track the bot's operations, receive performance data, and even control its movements from a distance using mobile devices or cloud platforms. This feature is especially valuable for managing large farms or inaccessible terrains.
- Integration with Autonomous Tractors and Drones: The seed metering bot can be part of a larger network of autonomous agricultural systems. When synchronized with autonomous tractors, drones, and harvesters, it contributes to a coordinated and data-rich ecosystem. This integration enhances operational efficiency, enables real-time field mapping, and allows better decision-making across the crop cycle. [13,14]

II. WORKING

The methodology for developing the automated seed metering bot is designed to systematically transform conceptual ideas into a functional prototype that meets the project objectives. This process involves multiple stages including design, component selection, integration, programming, and iterative testing to ensure precise and reliable operation in agricultural environments.

A. *Requirement Gathering and Analysis*

- Study traditional and existing automated seed sowing techniques to understand limitations and areas for improvement.
- Define critical parameters such as seed size, sowing depth, planting density, desired bot speed, field terrain type, and environmental factors.
- Finalize specifications for mechanical components (hopper capacity, metering disc hole size), electronic modules (motor voltage, sensor range), and control logic.

B. *Mechanical Design and Prototyping*

- Use CAD software (such as SolidWorks or AutoCAD) to design the chassis, seed hopper, metering disc, and seed delivery system.
- The chassis is designed to maintain stability and balance, accommodating the weight of the hopper, motors, and electronics.
- Select materials considering durability, weight, and cost-effectiveness—typically lightweight metals or polymers.
- The seed metering disc is designed with precision-drilled holes sized according to seed type to control seed release rate and spacing.
- Fabricate the parts using 3D printing, laser cutting, or manual machining, followed by assembly.

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C. Electronics Selection and Assembly

- Choose an Arduino Uno microcontroller for its ease of programming and sufficient I/O ports.
- Select 12V DC geared motors with a speed of approximately 300 RPM for controlled mobility, paired with motor drivers (L298N or similar) to handle power requirements.
- Use a servo motor to rotate the seed metering disc; servo precision enables accurate seed drop timing.
- Integrate ultrasonic sensors mounted at the front and sides of the bot for real-time obstacle detection.
- Set up a power management system using rechargeable lithium-ion batteries, including voltage regulators and safety fuses.

D. Software Development and Control Logic

- Develop firmware for the Arduino to manage multiple tasks:
  - Control the servo motor to rotate the metering disc at specific intervals based on programmed seed rate.
  - Operate the DC motors for forward, reverse, and turning motions using PWM signals for speed control.
  - Continuously monitor ultrasonic sensor readings to detect obstacles and trigger immediate stop or avoidance protocols.
- Implement state machines or interrupt-driven code to handle real-time sensor inputs and motor commands simultaneously.
- Program calibration routines for initial setup to synchronize seed release rate with robot speed.

E. System Integration

- Assemble mechanical and electronic components on the chassis.
- Wire all electrical components carefully, ensuring proper grounding and insulation.
- Test individual subsystems (motor movement, seed metering, sensor response) independently before full integration.
- Integrate the subsystems and test the entire system to verify communication and coordination between components.

F. Testing and Validation

- Perform static tests of the seed metering disc to confirm that one seed is dispensed per hole per rotation.
- Test the bot’s movement on flat and uneven terrain, adjusting motor speed and steering control as needed.
- Validate obstacle detection by placing various objects and confirming that the bot stops or reroutes correctly.
- Conduct field trials to measure seed spacing accuracy and assess the system’s robustness under real agricultural conditions.

G. Performance Optimization

- Analyze data from tests to identify delays, inconsistencies, or failures in seed dispensing or navigation.
- Tune motor speed control parameters and servo rotation intervals for optimal synchronization.
- Improve obstacle detection algorithms to minimize false positives and negatives.
- Enhance power management to maximize battery life during continuous operation.

H. Documentation and Reporting

- Maintain detailed logs of design iterations, testing results, and troubleshooting steps.
- Prepare technical documentation including circuit diagrams, mechanical drawings, and software flowcharts.
- Summarize findings and suggest improvements for future development such as GPS navigation, wireless control, and additional functionalities like fertilization or weed control

III. CAD DESIGN DESCRIPTION OF MATERIAL AND COMPONENT

A. Metering Disc

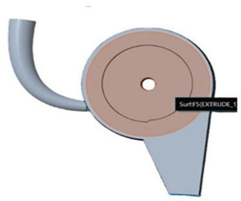

Fig.1 Metering Disc

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Working Principle of Metering Disc:

The metering disc is a crucial component in the seed sowing mechanism that ensures accurate and uniform distribution of seeds. Its working is based on the principle of mechanical indexing and controlled seed release.

The disc is a flat circular plate made of lightweight material, with evenly spaced holes drilled along a circular path near its edge. These holes act as seed pockets and are sized to accommodate only one seed at a time, depending on the seed type (e.g., wheat, soybean, maize).

The disc is mounted horizontally below the seed hopper and is rotated by a servo motor at fixed intervals, as controlled by a microcontroller (Arduino Uno). As the disc rotates, each hole passes under the hopper opening, allowing a single seed to drop into the hole due to gravity. When the hole reaches the outlet side, the seed falls through the delivery pipe into the soil.

This mechanism ensures one seed per hole per rotation, maintaining equal spacing between seeds. The speed of the disc's rotation and the number of holes determine the sowing rate. This method minimizes seed loss, ensures uniform crop spacing, and improves overall yield in precision agriculture.

Feeder

Fig.2 Feeder

The feeder is responsible for guiding the seeds from the hopper to the metering mechanism. It ensures a continuous flow of seeds and avoids clogging. Seeds are pulled from the hopper by gravity and directed towards the metering disc. The feeder's design ensures that only a limited number of seeds are available to the disc at a time, preventing overloading.

Suction (Vacuum) Mechanism

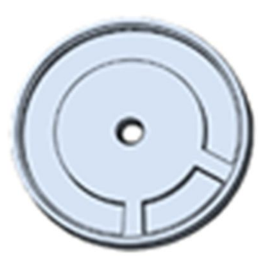

Fig.3 Suction

If your system uses suction-based seed picking (common in high-end seeders), suction holes on the disc use negative pressure to pick one seed at a time. A small vacuum pump creates low pressure, and each hole on the rotating disc holds a seed by suction. When the hole reaches the delivery outlet, suction is cut off, and the seed drops into the soil. This method enhances precision in seed metering, especially for lightweight or irregular-shaped seeds.

Outlet Pipe (Delivery Pipe)

Fig.4 Outlet pipe(Delivery Pipe)

The outlet or delivery pipe guides the seed from the metering disc to the soil. Once a seed is released from the hole in the rotating disc, it falls vertically through the pipe and is directly deposited into the ground. The pipe ensures a straight and controlled fall, maintaining accuracy in seed placement and reducing bounce or deflection during sowing.

Impeller

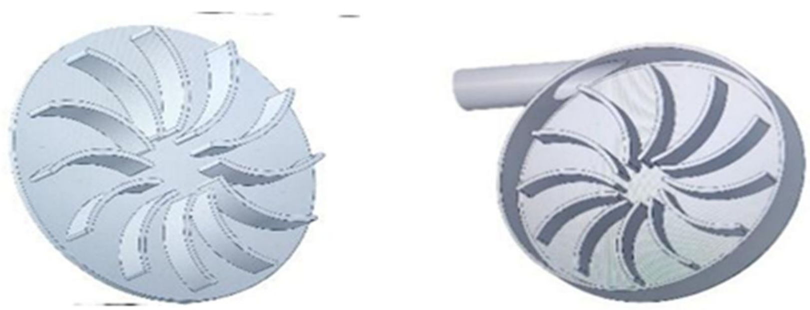

Fig.5 Impeller

In suction-based systems, the impeller is part of the blower or vacuum pump. It rotates at high speed, creating airflow that either generates suction to hold the seed or pressure to eject the seed (in pneumatic metering systems). The impeller's design and speed determine the pressure level and ensure a stable suction force for reliable seed handling

Middle Disc

Fig.6 Middle Disc

The middle disc, also known as the metering disc, is the heart of the seed metering unit. It rotates at a fixed interval using a servo motor. It contains holes or pockets around its periphery. As it rotates, each pocket aligns with the feeder and captures one seed. The seed is carried to the outlet position, where it drops into the delivery pipe. The disc’s hole size and spacing determine the seed type compatibility and spacing in the field

B. Microcontroller

A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system. It combines a processor core, memory, and programmable input/output peripherals on a single chip. Microcontrollers are widely used in applications that require automation and control, such as robotics, industrial machinery, automotive systems, and consumer electronics. Their ability to process inputs, execute instructions, and generate outputs in real-time makes them essential in modern embedded systems. For this project, the microcontroller serves as the brain of the system, coordinating all functional components and ensuring efficient, reliable performance.

The Arduino Uno is a widely used open-source microcontroller board based on the ATmega328P microcontroller. It is especially popular among beginners, students, and hobbyists due to its simplicity, affordability, and ease of programming. The board operates at 5 volts and can be powered either through a USB connection or an external power supply ranging from 7 to 12 volts. It features 14 digital input/output pins, of which 6 can be used as Pulse Width Modulation (PWM) outputs, and 6 analog input pins for reading varying voltage levels, typically from sensors.

C. DC Motor

A DC motor is an electromechanical device that converts direct current electrical energy into mechanical rotational motion. It functions based on the Lorentz force principle, where a current-carrying conductor placed in a magnetic field experiences a torque, causing it to rotate. This fundamental principle allows DC motors to deliver quick and controllable mechanical motion, making them highly suitable for applications requiring speed regulation, directional control, and fast response times.

DC motors are widely used in robotics, automation systems, and small-scale mechanical setups due to their high torque, smooth operation, and simple interfacing with microcontrollers. Depending on the design, they can be brushed (simple and cost-effective but require periodic maintenance) or brushless (more efficient and durable, but require more complex control systems).

In this project, we use a 12V DC motor with a rated speed of 300 RPM (Revolutions Per Minute). This specification ensures a good balance between speed and torque, making it ideal for the movement of the automated seed metering bot. The motor is used to drive the wheels, providing forward, reverse, and turning motion, and is controlled via a motor driver module (e.g., L298N) connected to the Arduino Uno.

Specifications of the DC Motor used:

- Voltage Rating: 12 Volts DC
- Speed: 300 RPM (No-load)
- Shaft Diameter: Typically 6 mm
- Torque: Approximately 2–3 kg·cm
- Motor Type: Brushed DC geared motor
- Direction Control: Reversible via H-bridge motor driver

By using PWM (Pulse Width Modulation) signals from the Arduino, the motor's speed and direction can be finely controlled. This capability is crucial for achieving accurate path following and timely seed placement, making the DC motor a central component in the bot’s mechanical actuation system.

D. Ultrasonic Sensor

An ultrasonic sensor measures distance by emitting high-frequency sound waves and detecting their reflections (echo) from nearby objects. It consists mainly of two parts: a transmitter that sends ultrasonic pulses and a receiver that listens for the echoes.

When connected to a microcontroller (like Arduino) via jumper wires, the sensor operates as follows:

1) Trigger Pulse: The microcontroller sends a short 10-microsecond electrical pulse through a jumper wire to the sensor’s trigger pin. This triggers the sensor to emit an ultrasonic burst of sound waves at about 40 kHz frequency.
2) Sound Wave Emission: The sensor’s transmitter converts the electrical trigger into ultrasonic sound waves that travel through the air.

3) Echo Reception: When these sound waves hit an obstacle, they reflect back to the sensor's echo pin.
4) Echo Pulse Timing: The sensor converts the reflected sound waves into an electrical signal. It sends a pulse on the echo pin, and the duration of this pulse corresponds to the time taken for the sound waves to travel to the obstacle and back.
5) Distance Calculation: The microcontroller measures the length of the echo pulse using jumper wire connections and calculates the distance using the formula:

Distance=Time×Speed of Sound2\text{Distance} = \frac{\text{Time} \times \text{Speed of Sound}}{2}Distance=2Time×Speed of Sound

Where:

- Time = duration of the echo pulse,
- Speed of Sound = approximately 343 m/s at room temperature,
- Division by 2 accounts for the round trip of the sound wave.
- Jumper wires are used to make the electrical connections between the ultrasonic sensor pins (VCC, GND, Trigger, Echo) and the microcontroller's pins.
- They allow easy and flexible wiring on a breadboard or development board without soldering.
- Good jumper wire connections ensure reliable transmission of trigger signals and accurate reception of echo pulses.

E. Working

The working of the Automatic Seed Metering Bot for Precision Agriculture involves a combination of mechanical design and intelligent control systems to ensure accurate seed placement and efficient field coverage. The process begins with loading seeds into the hopper, which serves as a reservoir. These seeds are gradually released into the metering disc, which is a circular plate embedded with evenly spaced holes. A servo motor, programmed through an Arduino Uno microcontroller, controls the rotation of the disc. At each defined time interval, the servo motor rotates the disc by a specific angle, aligning one hole at a time with the outlet. This results in the release of one seed per rotation, enabling precise and uniform seed spacing.

Once the seed exits the metering disc, it travels through a delivery pipe that directs it straight into the soil. Simultaneously, the bot's movement is powered by DC motors mounted on the chassis. These motors are governed by motor driver circuits that receive signals from the Arduino. The movement speed is controlled to synchronize with the seed dispensing rate, maintaining consistent sowing depth and distance.

To enhance navigation and automation, a GPS module is integrated into the bot. This module enables it to follow predefined field paths, reducing the chances of overlap or missed zones. For operational safety and smart decision-making, an ultrasonic sensor is installed at the front of the bot. This sensor continuously scans for obstacles in the bot's path. Upon detecting any obstruction, the system commands the motor to halt operation temporarily, ensuring there is no damage to the device or the field.

This entire system is powered by a rechargeable battery, making the bot portable and suitable for use in remote farming areas. The integration of mechanical precision, sensor feedback, and automated control makes this bot an effective solution for modern, sustainable agriculture.

IV. CONCLUSION

1) Designed a robust mechanical system incorporating a seed metering disc with accurately sized holes to release one seed per rotation, ensuring uniform spacing.
2) Implementing precise actuation control using servo motors for the seed metering mechanism, allowing programmable intervals for different seed types and sowing rates.
3) Developing an autonomous navigation system powered by DC motors (12V, 300 RPM) for movement, controlled via motor drivers, ensuring smooth and controlled field traversal.
4) Integrating obstacle detection sensors (ultrasonic) to enhance operational safety by detecting and pausing or rerouting around obstacles autonomously.
5) Utilizing Arduino Uno microcontroller as the central processing unit for sensor data acquisition, motor control, and coordination of sowing operations.
6) Ensuring modularity and scalability in design so that the system can be adapted for different crops, seed sizes, and farm sizes.
7) Evaluating the system's performance in real or simulated field environments to verify seed placement accuracy, operational reliability, and energy efficiency.

8) Exploring potential for future enhancements like remote monitoring, GPS-based path tracking, variable-rate seeding based on soil data, and integration with other autonomous farm machinery.
9) Promoting sustainable agricultural practices by reducing seed wastage, optimizing input usage, and minimizing manual labour requirements.
10) Developing a cost-effective prototype accessible to small and medium-scale farmers to democratize access to precision farming technologies.

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