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Design and Implementation of An Automated Seed Sowing Robot with the Precession Irrigation and Environmental Monitoring for Smart Farming

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ABSTRACT:
This paper demonstrates the design and construction of an automated seed Sower or seed hand system with precision irrigation and environmental scanner to be used in smart agriculture. The system is constructed to minimise manual labour, enhance the precision of sowing, as well as efficient application of water and resources. The robot moves autonomously with a control unit made of a microcontroller that coordinates seed dispensing, movement and irrigation functions. One of the seed sowing mechanisms is that the seeds are planted at a constant depth and distance which enhances a uniform growth and consistency in yield. To facilitate precision irrigation, soil moisture sensors constantly observe the field conditions and control the water supply to the field only when necessary, so as to avoid overwatering and waste. Moreover, real-time monitoring of such environmental parameters as temperature and humidity is monitored, which helps to comprehend the conditions in crops. The data obtained can be utilized in making timely decisions and better management of the farms. The system was put under controlled conditions and it proved to be a reliable performance in the matters of seed placement and water management. The findings reveal that the solution is capable of improving the productivity and reducing the human labour and the cost of operations, thus suitability in the current agricultural operations.

KEYWORDS: Automated Seed Sowing, Precision Irrigation, Smart Farming, Arduino, IoT in Agriculture, Soil Moisture Monitoring, Environmental Monitoring.

INTRODUCTION:

A number of articles in the literature point out that inadequate irrigation practices, absence of real-time monitoring and scarcity of water have been the key issues in agriculture. Most of the existing systems use hand watering that often leads to either excess or inadequate irrigation, wastage of water, and reduced crop production. Some of the limitations of some of the IoT systems discussed in the literature are single-mode operation, low environmental sensing accuracy, no farmer notifications, and ambiguous data storage to future planning. These constraints necessitate an intelligent and better dependable irrigation technology. Based on these failures, the objective of this project is to develop a system that would require the use of data and AI-based analysis to assist in decision-making besides automating irrigation. In this regard we decided to use the IoT and GSM backup to install the AI-enabled dual mode smart irrigation system. The ultimate goal of this project will be to help farmers to conserve water, limit labour, and improve crop growth. We apply sensors in order to measure the temperature, humidity and moisture content in the soil. These values are used to automatically activate or deactivate the water pump. Also, it can work both manually and automatically, having full control of farmers as required. The GSM module will ensure that the farmer is aware of what is going on as he/she receives SMS notifications even when the internet is not available. All the data has been stored in Google Sheets and therefore it would be easy to analyze the past data and as a result farmers will be able to plan better. This program enhances the productivity, application, and smartness of irrigation on modern and rural agriculture. Agriculture is one of the greatest aspects of our lives as it gives us food; however, the current farmers are exposed to numerous difficulties. The lack of water, or the lack of sufficient amounts of water to be used by crops, is one of the primary problems. In using the traditional irrigation methods, many farmers rely on guesswork to switch the pump on and off. This often leads to either under or excess water supply to the plants. Excessive water may damage crops and insufficient water may weaken them and make them dry. This has cost farmers time, money, and effort. As the literature review states, many systems focus on the reading of QR codes, scanning of expired goods, or using apps to monitor information. Although these solutions can be helpful in their corresponding fields, they all point out one thing people are prone to forget things or forget the details or simply are not able to access real-time information. On the same note, the farmers are likely to fail to provide crops with water at the right time or they may not necessarily be in the field all the time. Others utilize sensors, applications, or automation in some of their research projects but fail to provide farmers with all-inclusive solutions to network, data loss, or alarm problems. This drives us to establish an improved system. When we look at farmers in the rural areas, we realize that most of them do not have a good internet. Some farmers are also confused by complex smartphone applications. They need a system that keeps them updated even without the internet which is available, is automated, and presents precise information. This was meant to come up with something practical, smart, and simple to apply in real farming conditions. Based on these reasons, we designed the AI-enabled dual mode smart irrigation system by employing the IoT and GSM backup. Our study will help farmers to produce better crops, save on water and reduce the number of workers. The microcontroller and sensors to be used in our solution include a NodeMCU and the following sensors; a soil moisture sensor to detect the amount of water in the soil, DHT11 temperature and humidity sensor. When the soil is dry, then the pump will be activated automatically. When the soil has enough water, the pump will be switched off. Should there be a case where the farmers would want to use the pump manually, they can also choose the manual option. The GSM module was added to make the system more dependable. This is even when there is no internet, which informs farmers about the irrigation via SMS. The data collected is also stored in Google Sheets to assist farmers to understand the weather and soil over a period of time. This means that they can plan better on future crops. Everything said and done, our project presents an ingenious, automated and farmer-friendly irrigation system that reduces wastage of water, saves time and will assist in the modern and traditional farming practices. Irrigation is therefore much easier, safer and more effective to everyone.

LITERATURE SURVEY:

These authors are [1] Sebastian Rosewick, Felix Schorlemer, Frank Kunemund (2023) who worked in the sphere of wireless sensor networks in smart agriculture and smart cities. They established a special sensor network that operates on the utilization of various kinds of mobile robots, such as ground robots and drones, to measure the data in farms, forests, and green fields. This mobile system can travel to a variety of locations and carry out more difficult work whereas the traditional sensor networks are not able to move or adapt to the new conditions. It employs recent multi-agent control and machine-learning techniques to analyze information itself. These researchers examined the perspectives of farmers on the adoption of smart agriculture technologies in India with a focus on mobile robotic network which has a solution to the main problem that fixed sensors have limited coverage and are not able to perform complex outdoor jobs. [2] Their work is oriented at the ways such tools as the IoT sensors, automation, robotics, and AI could be used to enhance the quality of crops and to decrease the amount of work which farmers should do. They held surveys within the delta of Tamil Nadu and processed the information with SPSS and MS excel. Their primary issue of interest is that a larger number of farmers are yet to embrace modern technologies because of ignorance, knowledge, and do not have support. Their work assists policy makers to know what farmers require such that intelligent agriculture can be expanded more and enhance rural development.[3]. These authors are Sami Salama Hussen Hajjaj and Khairul Salleh Mohamed Sahari (2020), who reviewed the area of agricultural robotics and discussed the reason why not all robots have been popularized in actual farms. Although the studies demonstrate that there are good designs of robots, they are not widely applied in real life as robots require robust support infrastructure. These will involve constant internet connection, human-robot interaction systems and a robot software sharing platform. In the absence of this structure the sophisticated robots will be impractical or too costly to afford by farmers. Their biggest finding is that the cost and the complexity of establishing such infrastructure does not allow the mass adoption of robots [4]. Taehyun Kim, Jeonghyun Baek, DongHyeok Im (2024)These authors were engaged in enhancing smart agriculture with the help of multi-sensing technology and a low-power wide-area communication (LPWAN). They paid attention to such problems as a lack of standardization in the processing of the data, as well as difficulties with the automation, and the long-term refusal to utilize the newest technology. As a solution to this, they developed an automated monitoring and analysis system based on the LwM2M protocol and LORA technology server platform that provided low-cost communication over long distances. Their system makes the process of data collection and analysis more effective and can be utilized in such applications as smart greenhouses and plant stress monitoring[5]. This group was engaged in building smart agriculture based on agriculture robots (Chenggong Zhai et al., 2023). They defined agricultural robots, how they function, and their development since the beginning. Their research indicates the application of robot technology to assist in smart agriculture by executing activities that are normally performed by human beings. They emphasize that there should be smart agriculture systems that involve robots to enhance output. Their primary issue was the increasing pressure on advanced farming practices and the difficulties with their application in large-scale farm industries by robots[6]. The authors Thilina N. Balasooriya et al. (2021) created an IoT smart watering system, which monitors the soil moisture level and the pH of the irrigation water. This is because most systems only check one parameter whereas this system takes into consideration both of them to support healthier growth of plants. Microcontrollers transmit real-time data to the cloud on the sensors, meaning farmers can monitor conditions on a mobile application. These researchers came up with a smart irrigation system which decides the amount of water the crops require by using sensors and weather information [7]. They have a system that automatically uses soil moisture and weather conditions and plant growth data to regulate irrigation. A mobile application was also used to handle the data. The system will minimize water consumption and increase crop production. The primary issue that they have addressed is that the conventional irrigation is wasteful of both water and energy due to its failure to take into account real-time environmental factors. [8]. M. J. The current work by Peter et al. (2024) is devoted to smart irrigation in the greenhouse setting with the use of IoT and cloud computing. Their system keeps track of soil moisture, weather conditions, and needs related to crops and uses this information to develop accurate irrigation programs. According to the outcome of experiments, the system conserves water and sustains or boosts crop yield. The central issue that they tackled is that of the water shortage, and the necessity of proper irrigation in the regulated settings, such as the greenhouse. [9]. M. S. R. These authors (Gupta et al., 2023) have introduced a Smart Irrigation Management System (SIMS) to the Indian agriculture industry. It has sensors to determine soil moisture, temperature and humidity and automatically regulates water supply. The mobile application will enable farmers to operate the irrigation either manually or automatically. Another special feature is the float switch that monitors the level of water in storage tanks. Their primary issue of concern is that water wastes and a failure to automate the traditional methods of irrigation. [10]. P. These researchers Sebastian Vindro Jude et al. (2023) have created SIYO, an intelligent irrigation system that is oriented at forecasting crop development and enhancing harvesting. It relies on numerous sensors to measure soil moisture, temperature, humidity and nutrients to offer the accurate and automatic watering. Their system enhances the efficiency of water, food nutrient use, and crop prediction accuracy as compared to the conventional methods. The issue that they have addressed primarily is the ineffectiveness of outdated irrigation techniques and insufficient information to forecast crop production.

PROPOSED METHODOLOGY:

The proposed methodology focuses on developing an integrated robotic system capable of performing seed sowing, irrigation, and environmental monitoring in a coordinated manner. The system is built around a microcontroller that acts as the central control unit, managing all sensing and actuation tasks. Initially, the robot is powered through a battery supply and programmed to follow a predefined path for field coverage using DC motors controlled by a motor driver. During operation, the digging mechanism creates small furrows in the soil at regular intervals. A servo-based seed dispensing unit then releases seeds into the furrows with controlled timing to maintain uniform spacing. Immediately after sowing, a soil closing mechanism covers the seeds to ensure proper placement and protection. For irrigation, the system uses sensor inputs to determine environmental conditions. Temperature and humidity sensors continuously monitor the surroundings, while soil moisture levels guide the activation of the water pump. Water is supplied only when necessary, ensuring efficient usage. All operational data and system status are displayed on an LCD for real-time monitoring. The methodology emphasizes synchronized operation between movement, sowing, and irrigation, resulting in a simple, cost-effective, and efficient solution suitable for small- and medium-scale farming.

BLOCK DIAGRAM:

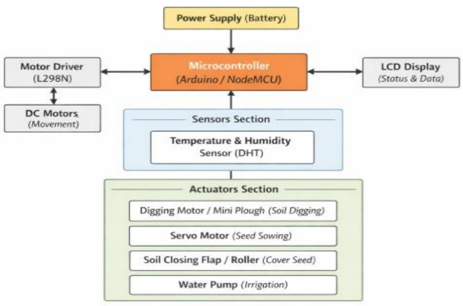

FIG 1: BLOCK DIAGRAM

HARDWARE WORK FLOW:

POWER SUPPLY (BATTERY)

FIG 2: POWER SUPPLY (BATTERY)

The battery is used as the main power of the whole robot which provides stable voltage to all electronics and mechanical parts. It is chosen depending on capacity and discharge rate to have it operate continuously in the field. Voltage is not left to fluctuate and destroy delicate circuit board elements such as the microcontroller and sensors. The robot is mobile because of its battery that enables it to operate in distant farms without being subjected to external power supply. Power management is deemed efficient and rechargeable batteries are preferred that can limit the cost of running and help being used repeatedly through the crop rotation.

MICROCONTROLLER (ARDUINO):

FIG 3: ARDUINO

A chip resembling a mini-computer that includes control circuits and functional units interconnected together to create a complex network. A small-sized chip, which tends to be similar to a mini-computer, with control circuits and functional units that are interconnected to make up a sophisticated network. Microcontroller is the central processing unit of the system which controls all the activities of the robot. It takes sensor inputs and processes the input into control signals which are sent to the actuators like the motors and pumps. It is coded to take control in the timing, movement and decision-making when it comes to sowing and irrigating. Arduino or NodeMCU was taken together to provide flexibility in its expansion and ease of programmability. It also contributes to the real time data management allowing one to control the operations properly. The microcontroller maintains the coordination of various modules in the system and the results in response and reliability to the different field conditions.

MOTOR DRIVER (L298N)

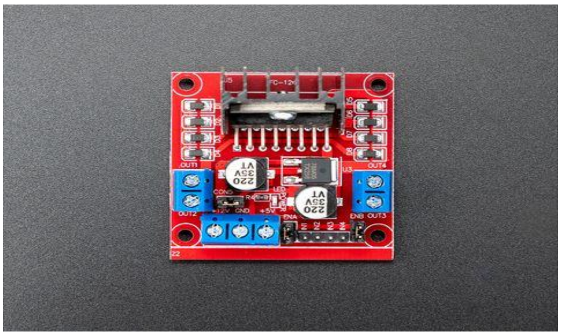

FIG 4: MOTOR DRIVER

Control of the direction and velocity of the DC motors that cause the robot to move in different directions is the duty of the motor driver. The microcontroller is not capable of providing enough current and therefore the driver serves as a bridge linking the controllable unit with the motors. It allows forward, retrogressive and turning movements through the base of voltage and current flow. L298N can be controlled with two motors, which have independent control of each wheel to enable improved navigation. It also guards against the overload conditions of the system. This element is critical in making sure that there is a smooth and manageable movement of the robot over rough farmlands.

DC MOTORS

FIG 5: DC MOTORS

DC motors give the mechanical movement necessary to the robot to move through the field. They are attached to the wheels and pulled using the motor driver to navigate them. The motors are selected according to the torque and speed specifications in order to cope with resistance of soil and field irregularities in the field. They enable the robot to work according to a preset route as they perform both sowing and irrigation duties. To ensure that movement remains constant and does not lead to misalignment when planting the seeds, there must be reliable motor performance. Stability and durability in agricultural use Properly mounted and aligned, they can be used over a long period.

BIOFEEDBACK THERMOMETER HUMID METER SYSTEM (DHT)

FIG 6: BIOFEEDBACK THERMOMETER HUMID METER SYSTEM (DHT)

Environmental factors are monitored using the temperature and humidity sensor to determine the environmental conditions of the crops. It will give immediate information that assists in knowing the microclimate of the field. Such data will be applicable in the evaluation of crop health and irrigation management. The sensor communicates with the microcontroller directly enabling the acquisition of data continuously. It is small in size and consumes very little power making it an embedded application. Effective sensing ensures that conditions are optimally maintained to promote the growth of plants and optimize yield and resource utilization when performing smart farming processes.

DIGGING MOTOR

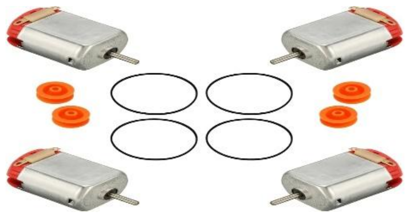

FIG 7: DIGGING MOTOR

The digging apparatus is made to form small trenches on the soil where the seeds are to be planted. It is propelled by a powerful motor that guarantees a stable depth and space on the forward motion. The mini plough is made in such a way that it can work under the various soils without showing much resistance. Effective seed germination is done by proper digging wherein there should be sufficient coverage of the soil and retention of moisture. The movement of the robot is synchronized with the motor so that the robot works uniformly. It is an element that makes the initial contact in the sowing process and has a direct effect on accuracy of planting.

SERVO MOTOR

FIG 8: SERVO MOTOR

The seed dispensing mechanism is controlled by the servo motor with a lot of accuracy. It works on instructions by the microcontroller to deploy seeds after a period of time. This guarantees even spacing of seeds which is significant in efficient crop production as well as resource exploitation. The servo mechanism has the capability to rotate it as needed and therefore it can be used in precise positioning. Consistent seed place comes as a result of its response time and reliability. The system is flexible by adjusting the control signals to suit other seed types and sowing requirements, which in turn increase the level of flexibility in agricultural applications.

SOIL CLOSING FLAP

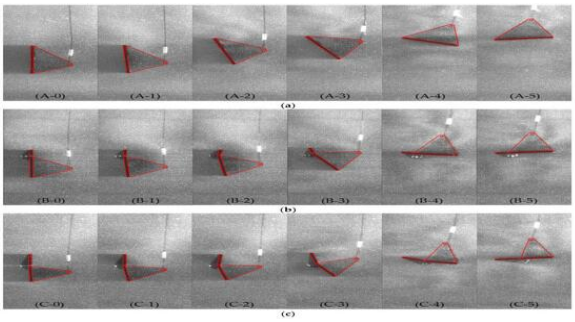

FIG 9: SOIL CLOSING FLAP

The process of seed cover after it has been deposited in the furrows is done by the soil closing mechanism. It is usually an overlay of a flap or roller that slides the soil back mildly over the seeds. The reason behind this step is to cushion seeds against exposure to the environment and enhance the process of germination. The mechanism works in harmony with the digging and sowing units so that the process continues. It also has a design such that the seeds are not moved around and at the same time covered. Adequate soil closure will be used to retain moisture and assist in early maturation of plants on a regular basis.

WATER PUMP

FIG 10: WATER PUMP

Water is supplied to the soil via the water pump after sowing or on demand programmed by the sensor. When the microcontroller is activated as required by the environment and soil needs, it functions. The pump is good, as it makes the water flow to be controlled with no overuse and facilitating effective irrigation nature. It is also linked to a source of water and has low power draw to fit the energy limit of the system. Early irrigation enhances seed germination and early growth. This element is crucial in the attainment of accuracy in irrigation of the automated system.

LCD DISPLAY

FIG 11: LCD DISPLAY

The LCD display shows real-time data on the functioning of the system, sensor readings and status of the functional system. It can assist users to control parameters like temperature and humidity as well as system activity directly on the device. It is more readily perceived through this visual feedback on the performance of the robot when it is in operation. The microcontroller is connected with the display and constantly updated. It improves the interaction of the user and does not involve external devices. The LCD will assist in enhancing the capability of supervision and fast decision-making when in the field by providing simple and clear information.

RESULT AND DISCUSSIONS:

The developed system was tested under controlled field conditions to evaluate its performance in seed sowing, irrigation, and environmental monitoring. The robot demonstrated consistent movement across the test area, maintaining a stable path with minimal deviation. The seed sowing mechanism achieved uniform spacing and depth, which are important factors for proper crop growth. The digging and soil covering units operated in coordination, ensuring that seeds were placed securely without exposure. The irrigation system responded effectively to sensor inputs, supplying water only when required. This reduced unnecessary water usage and maintained adequate soil moisture for seed germination. The temperature and humidity sensor provided continuous environmental data, which was displayed in real time on the LCD. The readings remained stable and useful for understanding field conditions during operation. During testing, the system showed reliable integration between hardware components, with synchronized functioning of motors, sensors, and control units. Minor delays were observed in actuation under uneven terrain, but they did not significantly affect overall performance. The results indicate that the system can reduce manual effort while improving accuracy in sowing and irrigation. This approach supports efficient farming practices and offers a practical solution for small-scale agricultural applications.

CONCLUSION:

The developed system demonstrates a practical approach to automating seed sowing with integrated irrigation and environmental monitoring. It reduces manual effort, improves seed placement accuracy, and ensures efficient water usage based on real-time conditions. The coordinated operation of mechanical and sensing units shows that such systems can support consistent and reliable farming practices. In the future, the design can be enhanced by adding GPS-based navigation for precise field mapping and IoT connectivity for remote monitoring. Improvements in obstacle detection and adaptability to different soil types can further increase its usability across varied agricultural environments.

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