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Autonomous Farming Robot

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Abstract: Pakistan's farming industry has significant problems, including low yields and inefficient use of essential resources such as water, fertilizer, and pesticides. In this era of modern technology, conventional methods of farming are unable to fulfil the agricultural demands in its respective time. Smart Farming is developing towards digitalized and data-driven operations, advanced decision support systems, smart analyses, and planning, among others. Agriculture is a perfect niche for innovations in the sphere of robotics. In this research microcontroller-based Autonomous Farming Robot is developed, that would allow farmers to use resources such as water and seeds more effectively and efficiently. Robot structure is modeled in AutoCAD software and has been constructed using wood and steel pipes. Further, different components like sensors, stepper motors and its drivers, DC motor and its driver, solenoid valve, water pump and relay module have been mounted on the robot structure and interfaced with ARM microcontroller. Three-dimensional movement inside the robot is added using stepper motor, so that robot can cover a large area and thus speed of work can be enhanced. In addition, a Web based Graphical User Interface (GUI) is designed using webserver controller, which provides a graphical assistance to users so that they can monitor the sensor data and operate the robot wirelessly with their own desired strategy of plantation. The system has been tested using coriander seeds on the soil bed and from the experimental results, it is found that designed system can execute complex tasks such as precise distribution of seeds, soil bed preparation, watering and monitoring agricultural parameters like temperature, humidity, and moisture appropriately.

Keywords: Autonomous Farming Robot, Farming Machine, Robot, Embedded system, IOT

1. Introduction

“End hungers achieve food security and improved nutrition and promote sustainable agriculture” [1] is that the second sustainable development goal of United Nations (UN) by 2030. Food means

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life and no one can think about living without food. This is the most fundamental human necessity and food security is one of the major global concerns of this century [2-3]. The agricultural sector determines the extent of food production and to an excessive level, the natural state of the earth. This indicates that the agricultural sector is still at the forefront of all other sectors of the economy [4]. Due to scarcity of enough trained manpower and for improvement of economy, the agricultural system must be modernized. For that purpose, farm has been surveyed which is known as Bhatti farm located near Ganghra Mori Hyderabad. The complete procedure of farming and the problems have been discussed with farmers. Troubles which they face, and their respective solutions have been mentioned as follows. The most prime is the scarcity of skilled labor. In this speedy world, people are moving from rural to urban areas. Hence, few people are left in the rural areas for farming [5-6]. This problem, the shortage of skilled labor in the rural areas can be somehow reduced by introducing modern technologies such as robotics, control, and automation in the field. The second prime concern is the lack of resources specially water. Water resources are reducing day by day [7]. In usual farming, Irrigation is done using large dams or Tube Wels. Consequently, water gets wasted because of waterlogging which is destructive to soil fertility. To reduce prime matters of waterlogging and wastage of water, water pump is introduced which is controlled via feedback therefore only required amount of water is sprayed precisely and accurately. The third prime concern is wastage of inputs specially seeds and lack of technical knowledge like High Yield Variety (HYV) seed [8-9]. Farmer mentioned during the interview that there are two types of seed which have been grown in two different ways depending on the type of seed [10]. The first one is that seeds are distributed by usual method with hands and much of them are wasted and second is that some seeds are sowed deeply in the soil which took more time and effort [11]. Our system is based on sowing the seeds deeply in the ground [12-13]. To utilize seeds efficiently, seed injector mechanism is introduced which can inject the seeds precisely, accurately, and efficiently. With the discussion, collaboration, and coordination with farmer, a list of seeds has been prepared which have been grow by sowing deeply in the soil and their respective season are mentioned below in Table 1.

Table 1: List of seeds grown by sowing deeply in the soil [14-15]

Seeds	Season
Coriander	Mid to late Autumn through to early Spring [16]
Ladyfinger	Best in summer / both season
Watermelon	Early Summer
Lobiya	Summer specially in August
Lemon	Spring
Spinach	Later winter/ Early spring/ Late summer
Ridged gourd (Tori)	Summer/ Rainy season
Apple gourds (Meha/tinda)	Summer-late autumn
Bottle gourds (Loki)	Summer/Monsoon
Bitter gourd (Karela)	Late spring-Early summer
Sorghum (Jower)	Summer (May to June)
Maize/Corn (Makkai)	Monsoon (March to October)

The fourth prime concern is the unawareness of humidity and temperature in the environment and moisture level of soil in which Farmers inject the seed. Mostly, they predict the temperature for each crop [16-17]. For that purpose, sensors have been interfaced with the robot to continuously monitor atmospheric parameters such as: humidity, temperature and moisture at real time and displays the data on mobile/desktop Graphical User Interface (GUI) [18-20].

The motive of our paper is to utilize modern technology, tools and techniques that contain robotics, control, and automation to resolve above problems and upgrade the productivity of farming methods and eventually the food. The object is to boost the speed of work by utilizing robotics and mechanical structured procedure and assisting farmers by providing them a superior picture of the current and historical context of the crop for a better decision making. Probably, such decisions will benefit mutually agriculture and country's economy by means of saving time and resources. There are so many causes which effects the agricultural sector such as: weather, temperature and other several factors which set hurdles in decision making process. This paper is an effort to take the decision by taking parameters in consideration. The objectives of this paper are as follows:

- To design and develop ARM microcontroller-based framework for robot to perform soil preparation, seed injection and watering tasks.
- Interfacing of sensors and components such as: stepper motors, drilling, seed injection and watering mechanisms with ARM controller and ESP32 Webserver respectively.
- To develop a communication protocol between ESP32 webserver and ARM controller.
- To develop a graphical user interface with ESP32 webserver using HTTP (Hypertext Transfer Protocol) and PHP (Hypertext Preprocessor) protocols in an Arduino IDE (Integrated development environment) so that user can operate the robot through that interface wirelessly.

2. Background and Literature Review

The increase of world population and simultaneously rising demand for high-quality food will bring a lot of challenges for future farming. Researchers are showing best efforts on advancement of farming to fulfil the longer-term need around the globe. Several works wiped out this field are described below:

Vidoni et al. [3] proposed a Bye Lab: An Agricultural Mobile Robot Prototype for Proximal Sensing and Precision Farming. They made a semi-autonomous robotic system which can sense and monitor the health status of orchards and vineyards. LIDAR technology with the aid of ad-hoc developed algorithm which have been adopted. P. Lottes, J. Behley et al. [4] designed Fully Convolutional Networks with Sequential Information for Robust Crop and Weed Detection in Precision Farming [21-22]. Its objective is to reduce the use of agrochemicals and introducing robots that can spray precisely or can perform mechanical weeding action for that purpose, they propose a plant classification system that relies on fully convolutional network by considering image sequences and can be able to differentiate between plant and weed without retraining of model. Anja-Tatjana Braun et al. [5] proposed a study on Farming in the era of industrie 4.0. This paper introduces some farming problems related to supply chain management and gave solutions. The agricultural sector needs to reorganize the supply chain concept because the reasons are heuristic characterized process, environmental conditions, and low division of work [23-24]. This study did not only deliver solution to above problems but also provide the foundation of new forms of work and business ideas for farming 4.0. Ilker Unar and Mehmat Topakci [6] developed remote and GPS-guided autonomous robot which may controlled through 3G internet and efficient for image processing applications [25-26]. This proposed system utilizes Joystick to regulate the direction of robot and Navigation software for directing the robot autonomously. N. S. Naik et al. [7] designed robot for seed sowing task. They designed four-wheel vehicle, controlled by LPC2148 microcontroller. Its sowed seed at distance and depth between crop and their rows. D. N. Vinod and T. Singh [8] developed autonomous agricultural farming robot in close field. This robot distributes seed and irrigation into field through ploughing blades and servo motor. This robot performs functionality of spray. The robot equipped with camera and send data to pc through Wi-Fi network. It works on ultrasonic and IR sensor [27-28]. This robot uses Wi-Fi alongside TCP/IP protocol, IP address, video is received on laptop for further processing. M.Naresh, Komatireddy Neha Reddy et al. [9] has developed robot drawing vehicle. it's wont to draw image very precisely by using stepper motors. It used code converter software, just to draw picture and import it through microcontroller by one click. Furthermore, it implemented server motor to lift and down the pen [29-30]. From above papers, analysis can be done that, many modern techniques have been introduced in the farming area to get the maximum product or to minimize the resources, but each has focused on one or two tasks by applying different strategies. Whereas single system has been developed for the multiple farming tasks. Now there's no space of using old methods of farming. Each task of farming must be robotized and automatic. Electronics, robotics, and automation should be implemented in farming. This paper shows the advantages of farming robot, and the use of farming robot gives efficient results to farmers. Farming machine having ability to perform following tasks precisely, accurately, and efficiently which are described below.

- Soil preparation accurately
- Seed sowing with solenoid valve and relay mechanism
- Watering using pump
- Monitoring agricultural parameters like moisture, humidity, and temperature and displays it on Graphical User Interface (GUI)

A robot has been commanded through a Graphical User Interface (GUI) whereas real time data has been monitored on the same user interface.

3. Research Methodology

Pakistan is an agricultural country and 24% of Gross Domestic Product (GDP) is also coming from this field. If latest technology like robotics, control and automation will be combined to this field then a county can receive more and more benefit. The aim of our paper is to develop a microcontroller-based system named as Autonomous Farming Robot for precision agriculture. The proposed system comprises of two sections, a mechanical and automation section and can perform the following tasks:

- *Monitor agricultural parameters*
- *Soil preparation using DC motor*
- *Seed injection precisely*
- *Watering*

Figure 1 shows the overall system design components of Auto Farming Robot.

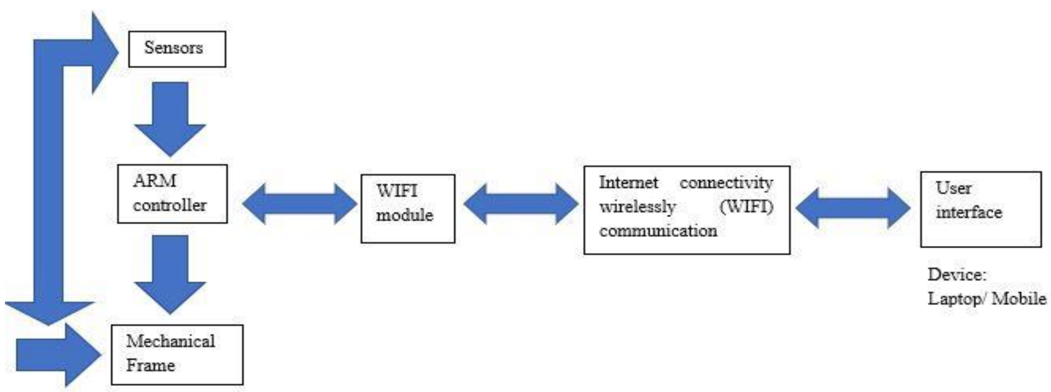

Fig. 1 - System Design Components of Autonomous Farming Robot

Here the brain of our system is the ARM controller which has been incorporated in the robot, the main reason for selecting is that it is rich in digital pins as the robot requires more digital pins due to a larger quantity of digital devices have been implemented in the robot. Furthermore, it provides a performance of CORTEX M-4 processing speed running at 168MHz frequency. Farmers usually predict the temperature, atmosphere, weather, and environment, and crop the seed according to their observation in the regular faming. But it is also observed that sometimes parameter does not vary according to the observation of farmer and in a result, they crop the specific seed at the wrong time and consequently they do not get the required product and receives less profit. So, for that purpose sensors are being interfaced in the microcontroller-based machine which gives results in the Graphical user interface (GUI) at real time, so that farmer can observe the parameters digitally and take the decision accordingly. Agricultural sector utilizes animals and tractors to cultivate the soil in regular farming. Perhaps, it would utilize more energy to drive tractors and pollution be caused by fuel. To overcome this drawback, we developed a microcontroller-based machine interfaced with motors that is controlled through motor driver using PWM (Pulse width modulation) technique. Drill bit that is attached with motor through drill chuck using rotational motion of motor enables to reach beneath the soil. The energy desire for this mechanism is much fewer as relative to tractors. Seeds are needed to sow in the soil after the preparation of soil. Hands were utilized to sows seeds that also utilizes time, energy, and skilled man in the regular farming. For that purpose, seed injector mechanism has been developed through the interfacing of solenoid valve with the controller that is being controlled by activating or deactivating its coil, which is used to sow seeds in this microcontroller-based machine. Through this way we can optimize the farming and can-do high value cropping in less expanse, time, and energy. Watering is being done using tube wells and distributed uniformly over the whole field in the regular farming which results in over application in some areas and under application in other and results dangerous effects on efficiency of land. This microcontroller-based system utilized water nozzles to water seeds precisely and accurately at the desired location to reduce water consumption and utilize it correctly. To operate the robot wirelessly, ESP32 is being implemented to provide WIFI (wireless fidelity) communication and user interface also has been developed. User interface has been developed in the robot to control the functionality and to monitor the parameters of the prototype. Wi-Fi is a family of wireless network protocols, depend on the IEEE 802.11 family of standards. It is utilized to deliver remote control of model across internet. The website sends information, which is then received by Esp32. On the laptop, the Apache HTTP server is utilized to construct a local server. The GET method is used by Esp32 to collect data from the server. The information sent to stm32 across max485 to rs485 module. For that purpose, Tx of Stm32 has been connected to DI (driver input) pin of max module and Rx is connected to RO (receiver out) pin and same is for ESP 32. The clock speed and bit rate of both MCU are same. A website that controls the robot's various functionalities is built using PHP and HTML. When a button is pressed, it sends a unique character to the controller through WIFI communication (ESP32), allowing the robot to recognize orders. PHP is a scripting language used on the server. It is a great way to make dynamic websites. HTML is utilized to characterize the structure and format of page by utilizing diverse tags and attributes. The figure 2 illustrates the workflow from website to the main controller via internet and ESP32 webserver.

Fig. 2 - Workflow from Website to Controller

Figure 3 represents the Mechanical Robot Model of Autonomous Farming of which mechanical structure is designed in AutoCAD software in a square shape. This design for our prototype has been chosen because it can cover a large area by three-dimensional movement through linear actuators and all required electronic and mechanical components can be fitted in this design. For that purpose, this design has been designed and developed for our Autonomous Farming Robot. Actuators alter the rotating motion of a stepper motor into linear motion. Pulleys and timing chain are used as linear actuators After modeling in CAD software, the structure has been designed practically by using these materials such as: wood, steel rods, timing chain and belt. Further stepper motors have been coupled with pulley.

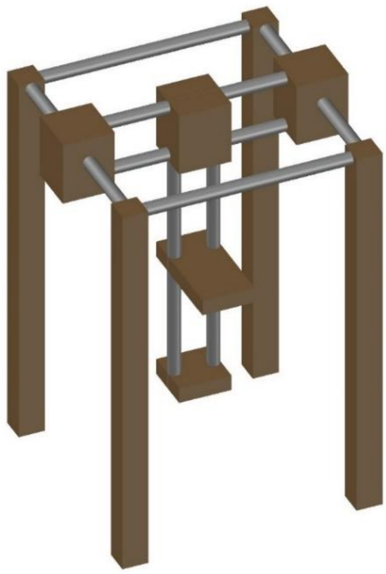

Fig. 3 - Mechanical Robot Model

Figure 4 illustrates the Hardware design of the agriculture robot, interfacing and integrating techniques of different components.

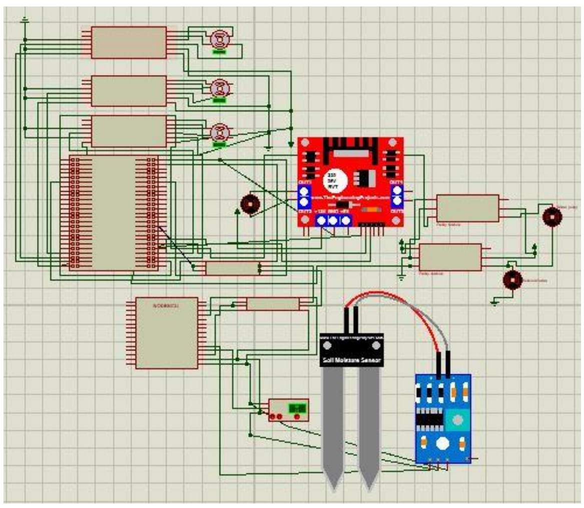

Fig. 4 - Hardware design of the Agriculture Robot

After designing, developing, and testing whole circuitry, it has been mounted and implemented on the Mechanical Model of Autonomous Farming Robot. This microcontroller-based machine can operate wirelessly through WIFI (wireless fidelity) communication as it has a user interface. It can be controlled using either Fully Autonomous Mode or User Control Mode. In Autonomous mode, the robot will start performing it's all tasks such as soil preparation, seed sowing and watering sequentially in an assigned area and halt afterwards by pressing the start autonomous mode. While, in user control mode, user will have privileges to start or stop any task at any time by clicking on any graphical respective buttons. The flow diagram explaining the sequence of operations is given in Figure 5

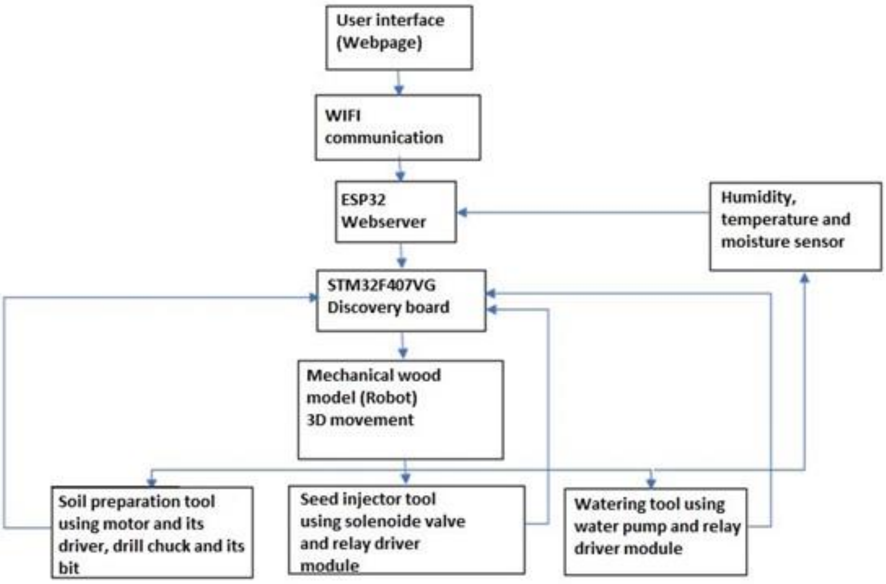

Fig. 5 - Flow chart of the Agriculture Robot

The final prototype of the proposed Autonomous Farming Robot is shown in Figure 6. The whole circuity is being incorporated and the stepper motors are also being added on the Mechanical model. The mechanical model is being designed using wood material and steel pipes are being used as the actuator for the smooth 3D movement. It can monitor the agricultural parameters such as humidity, temperature, and moisture and can perform the following tasks, to prepare the soil, to throw the seeds and to water the soil at the specified location.

Fig. 6 - Prototype of Autonomous Farming Robot

4. Results and Discussion

This section presents the experimental results and working mechanism of the Autonomous Farming Robot.

4.1 Soil Bed

For testing the working of robot, soil bed has been prepared and placed under the robot model to observe the response as shown in Figure 7. The soil bed has been designed having 20 inches length, 17 inches width and 5 inches height.

Fig. 7 - Soil Bed

4.2 Graphical User Interface (GUI) for the agriculture robot

The robot is operated over the internet. The website and the exp32 are both linked to the same localhost at first. With its SSID and Password set, the ESP32 is ready to link to any accessible Wi-Fi network. The ESP32 is a client now. This client uses port 80 to connect to the local server. The client then uses the HTTP/1.1 GET Method to retrieve data from the webpage. HTML and PHP are used to build the website. On the server side, PHP is utilized to deliver the data. Over the server, different data is sent based on the status of each button. The info changes when a button is pressed. The data is received by ESP32, which is functioning as a client, and the needed work is completed.

Figure 8 and 9 represents the graphical interface view in an ideal state and when all the buttons are pressed respectively.

Information collected at ESP32 when no button is pressed.

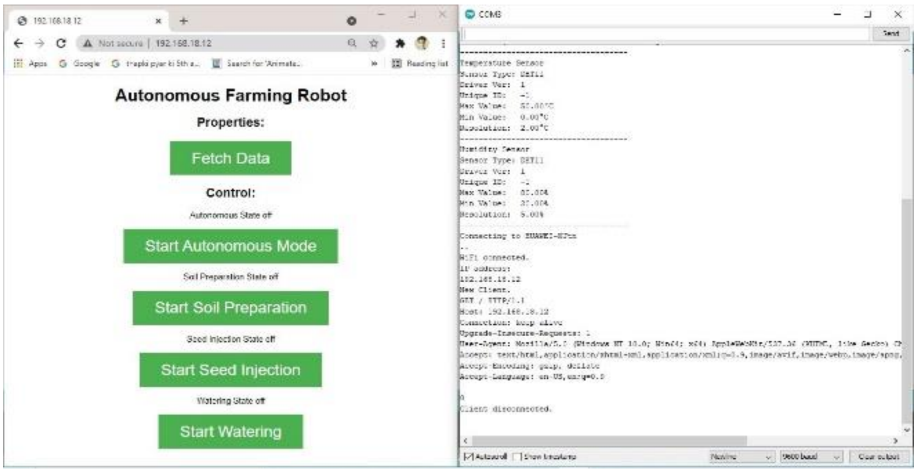

Fig. 8 - GUI image in general state Information collected at ESP32 when each button is pressed.

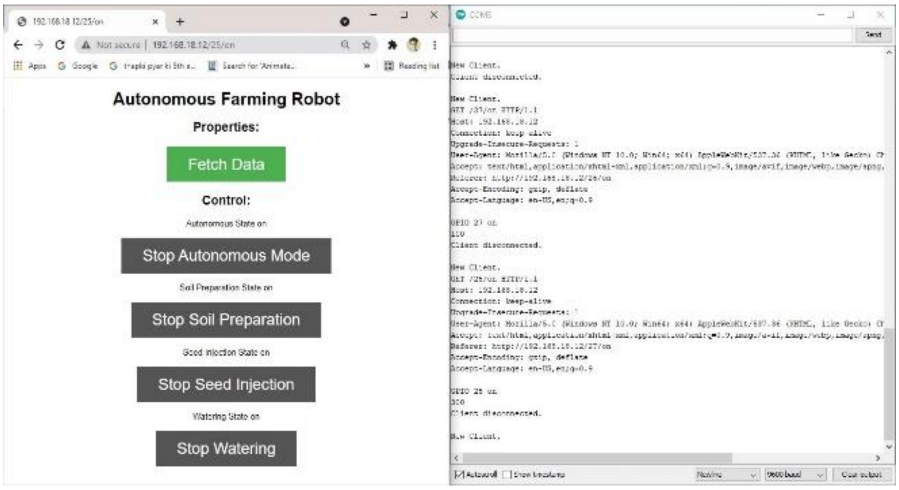

Fig. 9 - GUI image when each button is pressed

4.3 Sensor response

DHT11 humidity and temperature sensor, and moisture sensor have been interfaced and results of sensors have been displayed on graphical user interface (GUI) under different conditions. DHT11 generates respective digital output, and it is less expansive which provides high reliability and excellent long-term stability. It involves a capacitive humidity measuring device and a thermal resistor to determine the encompassing mid-air and yields an alphanumeric signal as the output on the data pin. Grove soil moisture sensor has both the analog and the digital output. It comprises of two probes, that allow the electric current to flow across the soil and then determine resistance numeric numbers to evaluate quantity of soil moisturization. These sensors have been interface to keep the continuous track of some parameters, such as humidity, temperature, and moisture.

Initially, soil is dry, and response of sensors under dry condition have been taken as shown in figure 10 and 11.

Fig. 10 - Dry Soil

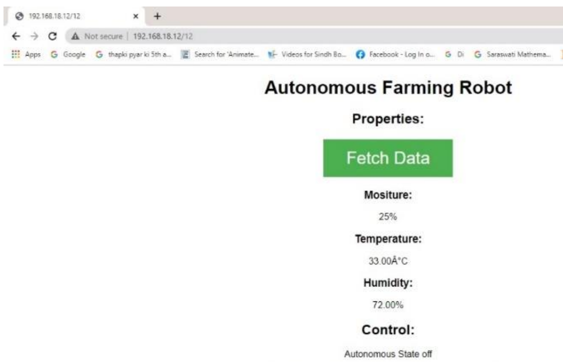

Fig. 11 - Sensor response under dry soil condition

Table 2 represents the sensor response under dry soil condition taken from the Graphical User Interface (GUI). As the response is taken under dry soil condition, so the moisturization level is also low as shown below.

Table 2: Sensor response under Dry soil condition

Humidity	Temperature	Moisture
72.00%	33.00ºC	25%

After taking results of dry soil, water have been poured on soil to make it wet and again results have been taking under wet condition as shown in figure 12 and 13.

Fig. 12 - Wet soil

Fig. 13 - Sensor response under wet soil condition

Table 3 represents the sensor response under wet soil condition taken from the Graphical User Interface (GUI). As the response is taken under wet soil condition, so the moisturization level is also high as shown below.

Table 3: Sensor response under wet soil condition

Humidity	Temperature	Moisture
74.00%	33.00ºC	99%

4.4 Soil Bed Preparation

The soil has been prepared using DC motor coupled with drill bit commanded by Graphical User Interface (GUI). The below figure 14 gives the view of soil bed preparation.

Fig. 14 - Soil bed preparation

4.5 Seeding Mechanism

Seed injector is designed using solenoid valve, as the command is given by GUI, the coil of valve gets excited, and it gets open, and seed dropped at the desired target as shown in figure 15.

Fig. 15 - Seeding

4.6 Watering

The following figure 16 gives the view of watering mechanism result which has done using water pump controlled by relay driver module.

Fig. 16 - Watering result

4.7 Coriander Plant

After the functionality of soil preparation, seed injection and watering mechanism, the soil bed has been placed in an open area and watered daily. After couple of days, seeds started to grow represented in Figure 17.

Fig. 17- Coriander plant

5. Conclusion

Pakistan's farming industry has large problems, such as low yields and inefficient use of vital sources together with water, fertilizer, and pesticides. In this period of advanced technology, traditional strategies of farming are not able to fulfil the farming requirement in its respective time. Smart Farming is growing toward digitalized and data-pushed operations, superior selection guide systems, smart analyses, and planning, amongst others. Agriculture is an ideal area of interest for improvements in the sphere of robotics. In this research microcontroller-based Autonomous Farming Robot is developed that can perform farming activities such as soil bed preparation, planting and watering are all possible with this robot. A drill bit with a DC motor via drill chuck was developed to convey nutrients to the up of the soil for soil bed preparation commanded through Graphical User Interface (GUI) while in usual farming, it is being done using tractors and consequently, it consumes more energy and it also become the cause of pollution. A seed injector along with a solenoid valve as well as relay have been utilized to throw the seeds precisely and accurately where in regular farming, it is being done by hands which consumes more time and effort additionally, it also become the cause of wastage of inputs. Water pressure have been controlled by a water pump for watering but in usual farming it is being done using tube wells which results over application in some areas and under application in other, so it become harmful for the crop and wastage of resources also occur. Due to the simultaneous functioning of the tools, the robot's capacity to move in three dimensions which enhances the efficiency of farming operations. To operate the robot from a distance, an interactive GUI was designed. This Web application allows users to control robots by allowing them to complete the tasks.

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