DESIGN AND DEVELOPMENT OF A SMART DEVICE FOR SUSTAINABLE AGRICULTURE

Abstract

This paper proposes a smart agricultural device that protects the crops by producing an alarming sound whenever motion is detected in its vicinity. This device includes a smart irrigation system that irrigates the farmland automatically when no moisture is detected in the soil. The current work runs on solar energy, making it an eco-friendly device.

Keywords: Agriculture, Sustainable device, Smart technology, Irrigation, Solar energy, PIR sensor, Moisture detector.

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I. INTRODUCTION

The Food and Agriculture Organization of the United Nations states that pests account for 40% of the loss of global agricultural produce [1]. Protecting crops against pests, birds, and intruding animals is challenging for farmers [2]. Therefore, this smart device has been proposed, which is a sensor-based device and has three modules that cater to the different needs of a farmer in the field of agriculture, such as protecting crops from getting damaged by intruding animals, birds, or pests and provide automatic irrigation for soil [3-4]. This whole system is powered by solar energy making it an eco-friendly agricultural device. It also provides the option of customization to the farmers who can choose to use all three modules to offer an all-in-one solution or use only one or a combination of two modules according to their requirement for an eco-friendly energy solution, protection of crops or irrigation.

James W. McAnulty [5] has developed an innovative crop protection apparatus designed to shield citrus trees from low-temperature stress. This system utilizes a fabric enclosure, constructed from lightweight yet durable material, which is supported by multiple ground-anchored frame elements. The enclosure is secured using a drawstring mechanism threaded through a series of eyelets along the fabric's edge, facilitating ease of installation and removal. Integral to the system is a heater and blower assembly that continuously circulates warm air within the covered space, thereby maintaining a favorable microclimate for the citrus plants during periods of cold weather. In contrast, Patrick B. Halahan et al. [6] have introduced a sophisticated smart irrigation system that incorporates a centralized control architecture equipped with a user interface and an intelligent scheduling module. The central control unit is responsible for generating irrigation schedules based on a variety of inputs. The smart scheduler comprises a data receiver, a processing unit, and a signal interface. The data receiver acquires and interprets the irrigation schedule, which the processor subsequently translates into a sequence of control signals compatible with the irrigation controller. The signal interface is tasked with relaying these signals to the irrigation regulator. This system leverages both rainfall data and site-specific information pertaining to each irrigation point, enabling the automatic application of an optimized irrigation regimen tailored to the needs of the landscape.

Daniel S. Thompson et al. [7] have worked on a solar panel shadowing system that can contemporaneously rotate large arrays of solar panels deposited in multiple rows, exercising a single drive system. The drive system comprises a single actuation device that drives multiple rotational restatement stages at each solar array row to tip the panels to the correct position. A binary ray structure within each row ensures applicable panel support during gyration and provides the frame for simplified installation and conservation. Work is demanded in the field of using detectors for agrarian technologies and the robotization of irrigation, as this may help increase the agrarian sector. This offer intends to contribute to smart agrarian technology.

Baoxi Zhang et al. [8] have worked on tone-powered humidity sensors using graphene oxide film constructed by asymmetric essence electrodes. The humidity detectors using graphene oxide film generally work under a bias voltage, which should be pretreated by asymmetric electrical reduction under a high bias voltage. Thus, it's set up that the oxygen-containing chemical group slants in the GO film can be set via coelectrochemical reduction by introducing asymmetric essence electrodes, similar to Au- Cu, Au-Zn, and Au-Al, without any electrical reduction treatment. A humidity-sensitive power creator is configured upon indispensable exposure to low and high relative moisture. It has been verified that the device with a planar configuration showed much more advanced power viscosity than the squeezed device. Grounded on such a nanogenerator with Au-Zn electrodes, a tone-powered humidity sensor displayed $\Delta I/ I0$ of 2800 when the droplet was deposited at a distance of 0.2 cm. Importantly, droplet spatial position was sensitively detected on a 5×5 detector array in touchless mode. Position estimation or localization is one of the crucial factors in IoT operations, similar to remote health monitoring and smart homes. Amongst device-free localization technologies, unresistant infrared (PIR) detectors are considered to be one of the promising options due to their low cost, low energy consumption, and good intricacy. I would like to bring to your attention that although the implementation of highly sophisticated systems can be intricate and delicate, they are still indispensable in real-world scenarios. Additionally, it would be highly beneficial to have readily available datasets for researchers to test their proposed localization and shadowing methodologies. Kan Ngamakeur et al. [9] have proposed a compact PIR device erected using market-of-the-shelf (COTS) PIR detectors and a dataset to address the challenges mentioned before. Therefore, we aim to design and develop an efficient, cost-effective yet technologically advanced solution for the farmers.

II. SCHEMATIC

In Fig.1, the workflow of the smart agriculture device can be seen. The solar power input derives from the solar energy, which is used to power the whole device. The energy is stored in a battery, which powers the PIR sensor, which detects the motion of any intruding creature in its particular range and produces sound to drive them away. The battery powers the switch to turn the speaker on or off. The solar power input is also connected to a BC547 transistor, which generates pulsive signals to create a flashing light effect to scare the animals, birds, or pests during nighttime. Lastly, the solar power input is connected to the water pump, which operates only when the moisture detector probe does not detect moisture in the soil. Therefore, the system irrigates the soil only in dry conditions.

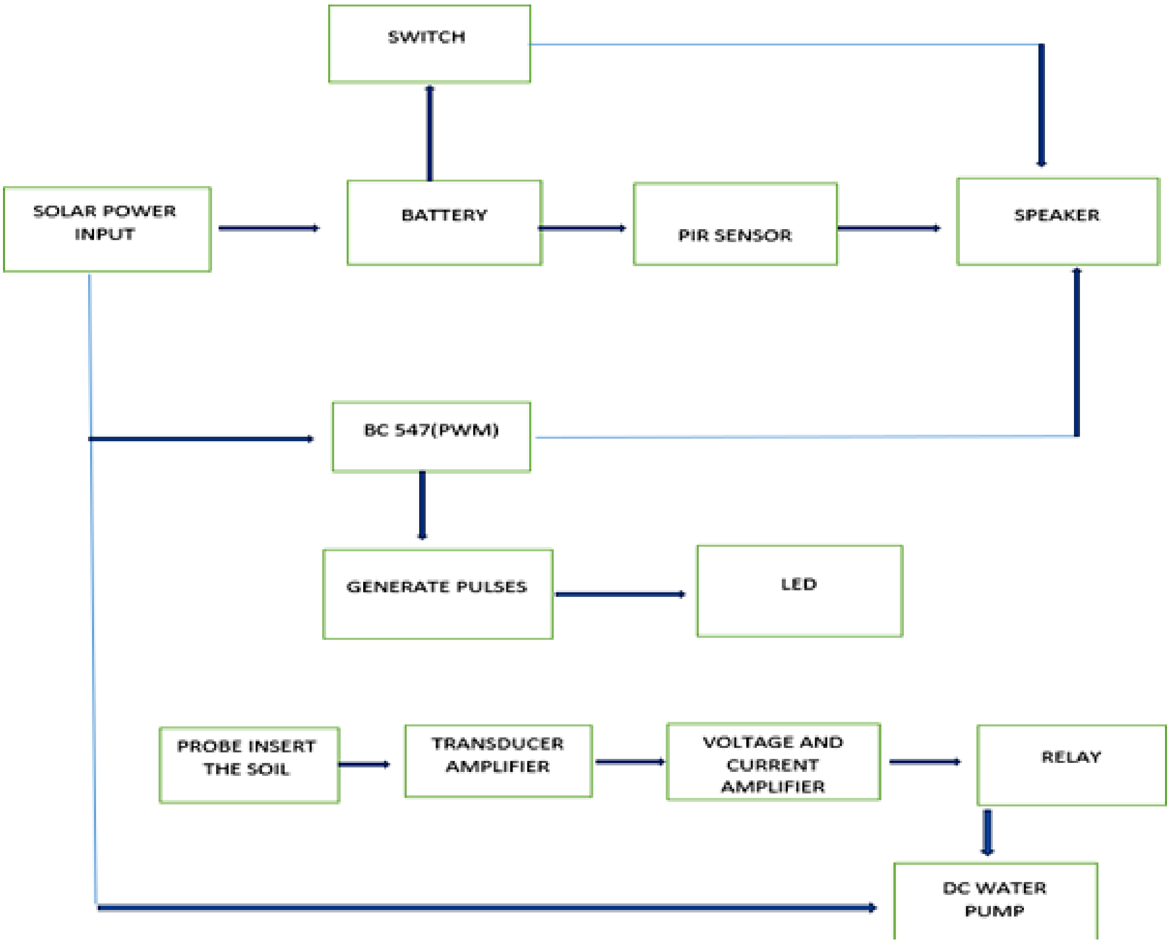

Figure 1: Schematic diagram of the smart agriculture device

III. PHYSICAL MODEL DEVELOPMENT

The device has three modules. The first module [Fig. 2. (a)], smart crop protector is a tower-like structure that consists of, a) speaker, b) PIR (Passive Infrared) sensor, c) resistor, d) capacitor, e) BC547 transistor, f) LED lights, g) on-off switch. The crop protector device intends to protect the crops from intruding animals, birds, and pests by using sound and light to drive them away from the crops whenever they come into the vicinity of the crops. The PIR sensor senses the motion in its particular range (the range can vary depending on the type of PIR sensor), rings the alarm and activates the LED lights to scare the intruders away. This is a less harmful way of keeping intruding animals, birds, and pests at bay in the absence of the farmer.

The second module [Fig. 2. (b)], smart irrigation system comprises of, a) LM358 Op-Amp IC (IC1), b) 555 Timer IC (IC2), c) CL100 Transistor, d) 5V Relay, e) Soil Moisture Sensor Probe, f) 1N4007 Diode, g) PCB board, h) Resistor, i) Capacitor, j) Electrolytic Capacitor, k) Ceramic Capacitor, l) Potentiometer/Pot, m) green and red light. This part of the smart agricultural device makes use of a soil moisture sensor probe to sense the moisture in the soil. When the soil gets dry and no moisture is sensed, the PCB board is sent a signal which then turns on the water pump to irrigate the soil. Once the soil is wet and the moisture sensor probe senses moisture the water pump turns off. This device works automatically and gives a cost-effective alternative for farmers to irrigate large farmlands.

The third module [Fig. 2. (c)], an Auto-rotating solar panel is the power source of this device and it consists of, a) an LDR sensor, b) a 12V solar panel, and c) a servo motor. This is the power source of the smart agricultural device. LDR sensors are installed on all four sides of the solar panel, oriented in the same direction as the panel itself. These sensors detect the intensity of sunlight and send a signal to the servo motor attached to the shaft on which the solar panel is mounted. As a result, the solar panel adjusts its position throughout the day to continually face the sun as it moves across the sky. This facilitates acquiring more solar energy efficiently, irrespective of the sun's position during the daytime.

The prototype development for the smart agricultural device system has assisted us in visualizing the design in physical form and testing the modules.

(a) (b) (c)

Figure 2: (a) Smart crop protector, **(b)** Smart irrigation system, **(c)** Auto-rotating solar panel

IV. TESTING OF THE MODULE

To test the module shown in Fig. 2 (a), a Passive Infrared (PIR) sensor is used to detect infrared light emitted by intrusive objects within its 50 cm field of view. When such objects are detected, the sensor triggers a buzzer. The sound is effective in preventing birds and insects from entering the protected area. This proactive measure significantly reduces crop damage and increases overall yield. While the current prototype uses CMOS and CCD camera-based sensors, future versions aim to improve bird and insect detection capabilities. This advancement will make the crop protection system more reliable and compact, ensuring greater efficiency in safeguarding crops from potential threats. The PIR sensor was tested both indoors and outdoors by placing an object at varying distances from the sensor to check the rate of motion detection.

Table 1: The data table of the experiment conducted with the module in Fig. 2 (a)

Sl. No.	Environment	Distance from the sensor module (cm)	Sensor Triggered
1	Indoor	70	False
2	Indoor	60	False
3	Indoor	50	True
4	Indoor	40	True
5	Outdoor	70	False
6	Outdoor	60	False
7	Outdoor	50	True
8	Outdoor	40	True

The module shown in Fig. 2 (b) has been tested on sandy soil. Sandy soil is highly porous and permeable, which means that the water retention capacity of the soil is very low, making it difficult for crop plants to get enough water. This results in the need for frequent irrigation, particularly for crops like rice (paddy), sugar beet, sugarcane, and soybean. These crops require more water per hectare in comparison to other crops. Therefore, the device can help to keep the soil moist, ensuring that the crops get a sufficient amount of water. As for the experiment, we have measured the field capacity, soil moisture, and water flow (in liters per hour). Table 2 below showcases the results of the experiment.

Table 2: The data table of the experiment conducted with the module in Fig. 2 (b)

Sl. No.	Field Capacity (g/kg)	Soil Moisture (g/kg)	Water Flow (Litre/hour)
1	350	400	0
2	350	349	0
3	350	260	110
4	350	250	144
5	350	270	56

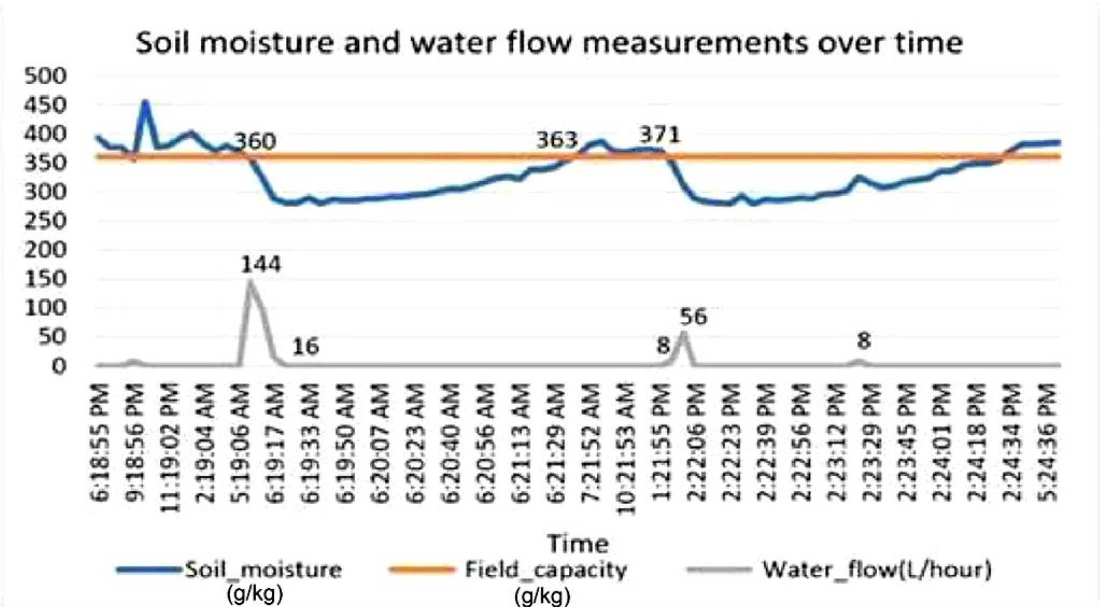

Figure 3: Soil moisture, field capacity, and water flow vs time graph

The graph in Fig. 3 shows the variation of soil moisture and water flow with time for a field capacity of 350 g/kg. The water flow occurs whenever the soil moisture drops, thus helping to retain the soil moisture.

In the module shown in Fig. 2 (c), a 360-degree rotating solar panel was tested thoroughly to evaluate its functionality and efficiency under various conditions. Initially, the panel's rotation mechanism was assembled and calibrated to ensure smooth movement. The operational testing involved observing the panel's ability to track the sun's position accurately and adjusting its orientation accordingly. The panel was also tested against environmental factors such as sunlight intensity, wind, and temperature changes to assess its performance and durability. Once the testing was completed, data collection and analysis were performed to check the panel's effectiveness. In the primary model, an "LDR" was used to track the sun's position, and it also has a removable battery that can be used for other purposes. The 12V solar panel's power output was tested under three different weather conditions.

Table 3: The data table of the experiment conducted with the module in Fig. 2 (c)

Sl. No.	Weather condition	Current (mA)	Power Output (W)
1	Sunny	148.8	1.79
2	Sunny	147.9	1.77
3	Sunny	149.3	1.79
4	Partially Sunny	74.8	0.90
5	Partially Sunny	73.6	0.88
6	Partially Sunny	73.4	0.88
7	Cloudy	22.3	0.27
8	Cloudy	22.5	0.27
9	Cloudy	22.1	0.27

This experimentation helped us gain an insight of the functionality of each of the three modules of this device system. We can draw the conclusion through the experimental data that, a) the false detection rate of the PIR sensor is negligible, b) the automatic irrigation system activates as the moisture of the soil falls below the field capacity as shown in Table 2, c) in order to maximize the output from the solar panel an energy storage system in the form of battery is essential, especially in unpredictable weather conditions.

V. CONCLUSION

A new smart agriculture device has been developed to help farmers reduce losses caused by animal, bird, or pest destruction of crops [10]. Moreover, the motion sensor will be replaced by the photogenic sensor so that it can detect the object from a distance and alarm the system. The automatic irrigation module of the device helps farmers water their farmland more effectively. The team is developing an irrigation system that provides data on crop and soil conditions to determine water requirements. The device is powered by a solar panel that rotates automatically to capture sunlight, which is stored in a battery and can also be used to power the farmer's house. The prototype has undergone testing in real-world scenarios on a smaller scale. The irrigation system has been tested for sandy soil, which is notoriously difficult to irrigate, and for crops that require high moisture content during cultivation. The team is developing an irrigation system that provides data on crop and soil conditions to determine water requirements. Detectors to expand the range of crops that can benefit from this irrigation system. The team is also considering developing an app-based interface that would allow users to control the device remotely.

The future scope of our work is to make this device smarter by adding features to recognize and differentiate between threatening and non-threatening objects to optimize the use of the alarm system by bringing optical sensing technologies into use [11]. There is a proposal to employ hyperspectral imaging in a smart irrigation system. This technology can capture intricate spectral responses with numerous bands, enabling it to identify even the slightest changes in ground coverage over a period of time. By detecting these variances, the system can tailor soil irrigation to the specific requirements of diverse soil types and crops, leading to optimal results. Also, the measurement of vegetation indexes on which the plant growth depends, assessing the fruit ripeness or detecting the presence of defects and diseases, is a key factor to gain high-quality fruit or vegetables. Such evaluation can be done using hyperspectral imaging. Hyperspectral imaging technology combines image analysis and visible/near-infrared spectroscopy [13].

REFERENCES

The following references have been cited in the paper:

[1] DTE Staff (2021, June 3), “At least 40% global crops lost to pests every year: FAO”, Down To Earth, https://www.downtoearth.org.in/news/agriculture/at-least-40-global-crops-lost-to-pests-every-year-fao-77252
[2] D. Karimi, J. Henry, D.D. Mann, Effect of using GPS Autosteer guidance systems on the eye-glance behavior and posture of tractor operators, J. Agric. Saf. Health 18 (2012) 309–318, https://doi.org/10.13031/2013.42332
[3] T.J. Esau, C.B. MacEachern, A.A. Farooque, Q.U. Zaman, Evaluation of Autosteer in rough terrain at low ground speed for commercial wild blueberry harvesting, Agronomy 11 (2021) 384, https://doi.org/10.3390/agronomy11020384.
[4] A. Ghobadpour, G. Monsalve, A. Cardenas, H. Mousazadeh, Off-Road electric vehicles and autonomous robots in the agricultural sector: trends, Challenges. Oppor. Veh. 4 (2022) 843–864, https://doi.org/10.3390/vehicles4030047
[5] James W. McAnulty, U.S. Patent No. US7637053B1 (29 Dec 2009)
[6] Patrick B. Halahan, J. Patrick Mcintyre, Mark Coopersmith, and Mark Puckett, U.S. patent No. US8948921B2 (03 Feb 2015)
[7] Daniel S. Thompson, Monty Mullins, Craig Stager, and Anthony Zante, U.S. Patent No. US8948921B2 (03 Feb 2015)
[8] Baoxi Zhang, Kaixuan Wang, Xinyang Ji, Shunyao Wang, Zhuo Ma, and Yunfeng Qiu,“ A self-powered moisture detector using graphene oxide film constructed by asymmetric metal electrode”, Journal of Alloys and Compounds, Elsevier (14 August 2019)
[9] Kan Ngamakeur, Sira Yongchareon, Jian Yu, and Saiful Islam, “Passive infrared sensor dataset and deep learning models for device-free indoor localization and tracking”, Journal of Pervasive and Mobile Computing,(14 November 2022).
[10] Mustapha, Baharuddin, AladinZayegh, and Rezaul K. Begg. “Ultrasonic And Infrared Sensors Performance in A Wireless Obstacle Detection System” Artificial Intelligence, Modelling and Simulation (AIMS), 2013 1st International Conference on. IEEE, 2013.
[11] Qiuhao Zhang, Jiaming Tang, Haoze Zheng, Chunyu Lin. “Efficient object detection method based on aerial optical sensors for remote sensing”,2022, 10 November.
[12] B. Lu, P. Dao, J. Liu, Y. He, J. Shang, Recent advances of hyperspectral imaging technology and applications in agriculture, Remote Sens. 12 (2020) 2659, https://doi.org/10.3390/rs12162659.
[13] A. Benelli, C. Cevoli, A. Fabbri, In-field hyperspectral imaging: an overview on the ground-based applications in agriculture, J. Agric. Eng. 51 (2020) 129–139, https://doi.org/10.4081/jae.2020.1030.