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Development and Performance Analysis of an IoT-Based Hybrid Multipurpose Machine for Small-Scale Farming

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Abstract

Agriculture remains the primary source of livelihood for over half of the Indian population; however, small-scale farmers, who account for more than 82% of this segment, face numerous challenges such as rising labor costs, exhaustion, and substantial investments required for modern machinery. This study focuses on creating a prototype machine that addresses the technological gap by designing an affordable and efficient IoT-based multipurpose agricultural machine. The machine's design utilizes an MS ladder frame structure and incorporates four essential agricultural functions: motorized seeding, irrigation, grass cutting, and ploughing.

This combined technology utilizing an Arduino UNO and an HC-05 Bluetooth Module can automatically perform tasks with accuracy and low torque through an application running on a smartphone, while also engaging in manual tasks such as ploughing that require high torque. The experimental results indicate that this machine can cover a 100m² areas in 45 minutes, representing a 62.5% decrease in time compared to traditional farming methods. Additionally, the machine demonstrates 92% efficiency in weed elimination and achieves a 40% reduction in water usage due to its effective water supply system. The cost associated with building this machine is 60% less than that of manual cultivation.

Keywords: Multipurpose Agricultural Machine, IoT, Arduino UNO, Bluetooth Control, Seeds Sowing, Grass Cutting, Smart Farming, Hybrid Mechatronics.

1. INTRODUCTION

It is true that the role played by agriculture cannot be ignored in many developing countries because the country's economic status depends on its agricultural sector. However, farmers utilize traditional techniques and physical labor to conduct agricultural work. Plowing, seed sowing, irrigation, and weeding are the major tasks that farmers carry out manually. This process requires much time, energy, and human labor. Hence, an increasing number of technologically advanced equipment are required to simplify farmers' tasks and increase agricultural efficiency.

It has been noted that automation is one of the fast-growing concepts due to technological advancement. Moreover, the application of IoT technology in the mechanical system will assist people in managing machinery remotely. IoT-driven agricultural machines will be able to perform multiple farming operations, reduce human effort, and improve the precision of the operations.

In the present research, it is imperative to address the development of the IoT-driven hybrid

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agricultural machinery that would be able to undertake various farming activities like ploughing, planting seeds, watering crops, and weeding. The operation of this device will be through electrical energy, and if need be, it could even be used manually.

It is important to point out that among the objectives of the project is the design, development, and testing of a cheap IoT-driven agricultural machinery that would be able to perform various functions.

A fundamental feature of the multipurpose device is its Hybrid Engagement Doctrine. While low-torque activities that necessitate accuracy are mechanized to guarantee Mission Accuracy, high-torque activities like ploughing would need the operator's interference to ensure Energy Endurance and, hence, Mission Success. In this research, the operational capabilities of the tested platform have been analyzed thoroughly. Particularly, its Operational Tempo and Logistic Efficiency have been examined comprehensively.

2. LITERATURE REVIEW

Designing of Multipurpose Agricultural Machine

Taneja and Kumar (2021) developed a multipurpose agriculture device, which had the ability to perform different farming activities through one mechanical mechanism. This invention had proven itself to be efficient and effective in small scale agricultural activities with fewer labor requirements. However, this device had no advanced automation and remote monitoring systems, and thus could not be used efficiently in precision farming.

Development of Multipurpose Agriculture Robot Using IoT Technology

Guha and Sarkar (2022) introduced a smart farm management system using IoT technology, where sensors, wireless networks, and microcontrollers would help in performing different farming activities through automated processes. As shown by the results, this approach was efficient in managing and controlling the farming activities. However, the system depended on good internet connectivity.

Automatic Control of Irrigation and Sowing Process Using Bluetooth Communication

Dhivya and Mary (2023) introduced an automatic irrigation and sowing system, which was developed using Arduino board, coupled with a Bluetooth module. This smart irrigation process helped in increasing yield and minimizing wastage. However, this invention only focused on irrigating and sowing activities. Other farming activities like ploughing and weeding were not incorporated into the design.

Seed Sowing Machine for Small-Scale Farming

According to Gopal and Murugan (2019), the seed sowing machine had been developed explicitly for small scale farming applications. The machine guaranteed consistent dispersion of seeds and enhanced efficiency in seed planting compared to manual techniques. The authors emphasized that seed planting machines played a critical role in lowering labor costs and improving productivity within agriculture. Nonetheless, the device could perform only one task without incorporating modern automation systems.

Automated Seed Sowing Machine with Arduino UNO and Stepper Motor

Patil and Jadhav (2022) invented an automated seed sowing machine through the incorporation of Arduino UNO and stepper motor. The apparatus ensured accurate seed spacing and minimized physical effort exerted by humans during planting. Nevertheless, the machine needed constant supervision, and it could not execute other agricultural tasks like irrigation and cutting..

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3. METHODOLOGY

The process of developing the IoT-based hybrid multipurpose agricultural machine was done following a series of steps involved in engineering. To begin with, the needs of the small-scale farms in respect to seeding, irrigation, and weeding were determined. On the basis of this, a suitable mechanical and component design was developed.

The machine frame and other components were fabricated. This involved making the machine frame and integrating the electrical components like the motor, water pump, sensors, and control unit among others in order to make it functional and operate automatically. Hybridization was done since the machine could run either manually or by using electrical power.

Finally, the machine was tested to examine its performance. Testing involved assessing how efficient it operated. After testing, analysis was done to determine the efficiency of the multipurpose agricultural machine in respect to small-scale farming.

Figure 1: Methodology Flowchart for Development of IoT-Based Hybrid Multipurpose Agricultural Machine

4. MACHINE CONFIGURATION AND STRUCTURAL LAYOUT

Machine Configuration

The structure of the machine designed for IoT-based multipurpose agricultural machine is engineered to undertake various farming operations in an efficient manner. The frame design of the machine is fabricated using mild steel, which offers enough strength, rigidity, and stability while carrying out the tasks in the field. The frame design of the machine serves as the basic frame structure, on which the rest of the mechanical and electronic elements are mounted.

The machine uses four wheels to facilitate the movement of the machine around the farm area. The machine also incorporates a drive motor, which is coupled with the wheel system, hence providing power to the whole machine. Finally, there is a seed sowing system that is mounted on the back end of the machine to facilitate the distribution of seeds uniformly across the soil surface. A watering system which consists of a water tank, pump, and delivery pipe is also included in the design of the machine to facilitate the irrigation process.

The plowing and weeding implements have been integrated into the structure of the machine on its lower end so that the machine can carry out both these processes simultaneously. The

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battery and controller of the machine have been fitted on the upper part of the machine.
Equipment to be used

Table 1. Equipments

Sr. No.	Equipment Name	Function / Description
1	Main Frame	Provides structural support to all components
2	Wheels	Enable movement of the machine in the field
3	DC Motor	Drives the wheels for machine motion
4	Motor Driver	Controls speed and direction of motor
5	Seed Sowing Unit	Dispenses seeds uniformly into soil
6	Ploughing Tool	Loosens soil for cultivation
7	Weeding Tool	Removes unwanted plants from soil
8	Water Tank	Stores water for irrigation
9	Water Pump	Supplies water to crops
10	Battery	Provides electrical power to system
11	Arduino Controller	Controls overall machine operation
12	Wireless Module (Bluetooth/Wi-Fi)	Enables remote control via smartphone
13	Chassis / Base Structure	Supports mechanical components
14	Pipe and Nozzle System	Delivers water to plants
15	Control Switches	Allows manual operation of system

5. SYSTEM ARCHITECTURE

The System architecture is structured to have mechanical, electrical, and control components integrated such that efficient multifunctional agricultural activities could be achieved. The microcontroller constitutes the control component of the machine that controls the overall performance of the machine.

Rechargeable 12V battery acts as the primary electrical energy source of the machine providing electricity for the motors, water pumps, sensors, and the controller. Motor driver plays a key role in controlling the rotational direction of the motors so that the machine could be able to go forward, backwards, and rotate. Seeding, irrigation, and ploughing systems are connected to the controller to perform their intended functions in agriculture.

Remote control through the use of a smartphone is made possible in this machine whereby the operations of the machine could be performed at a distance via the use of Bluetooth or Wi-Fi technologies.

The block diagram presented in Figure 2 shows how the power supply, control unit, sensors, and mechanical components interact with each other in the multipurpose agricultural machine.

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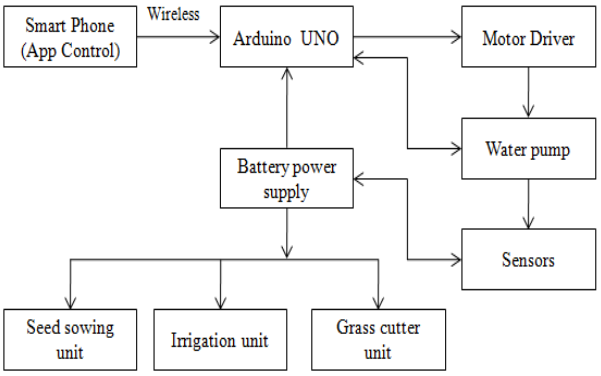

Figure 2. System Block Diagram of IoT-Based Hybrid Multipurpose Agricultural Machine

6. WORKING PRINCIPLE

The constructed IoT-based multipurpose hybrid agricultural machine operates based on the principle of the use of electronics in combination with mechanical processes for the accomplishment of various agricultural activities such as ploughing, planting seeds, irrigation, and weed removal in one device. The machine is driven using an electrical rechargeable battery and can be operated using manual techniques as well as remotely by use of wireless communication components.

The process of operation starts by charging of the control unit and electric motors through the use of electrical energy from the batteries. Electrical energy is then converted to mechanical energy using DC motors, causing the rotation of the wheels. As the machine moves along, the ploughing equipment attached to the bottom front end of the machine loosens the soil, readying it for planting.

At the same time, the seed planting equipment sprinkles the seeds in the prepared ground uniformly at set distances apart. Irrigation is carried out by pumping water into the soil via pipes from the water reservoir. The weed cutter will remove any weeds that may be growing inside the field.

Through electricity and human interaction, the machine will function using both forms of energy input based on the situation. Using electronic sensors and wireless control increases efficiency and decreases the physical energy needed.

7. PERFORMANCE ANALYSIS

In order to measure the effectiveness of the IoT-based hybrid multipurpose agricultural machine, a series of experiments have been conducted. It was tested in practical agricultural activities including ploughing, seeding, irrigation, and weed removal. The following criteria for machine performance were taken into account in this test: speed, worktime, energy consumption, and user-friendliness.

It was found during the experiment that the device operated reliably while moving across the field, and its soil penetration was high with the ploughing tool. The seeds were evenly distributed at equal distances due to the seeding tool, saving seeds in the process. The irrigation tool irrigated the soil due to the pump and pipeline. Finally, the weed removal tool removed weeds.

Due to the hybrid operation method, when electricity and manual labor could be utilized, the machine functioned continuously. Additionally, the machine operation was facilitated by the

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IoT system and the control system, which made the machine more convenient to operate. Based on the results of the experiments, the machine proved to work effectively.

8. CONCLUSION

As shown in practice, the development of hybrid agricultural machinery on the basis of IoT has turned out to be an extremely effective method for conducting several farming activities using one single piece of machinery. In particular, the agricultural machine has such agricultural operations as plowing, seed sowing, irrigation, and weeding.
In accordance with the experimental results, the efficiency of agricultural machinery is quite high. Thus, due to its hybrid features, it is possible to conduct farm activities both electronically and manually. In conclusion, it can be said that the construction of agricultural machinery ensures reliable and long-term performance when performing agricultural operations.To conclude, the developed agricultural device brings about higher efficiency of farm management, lower operational time, and financial expenses for small farmers.

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