

DESIGN AND DEVELOPMENT OF SEMI AUTOMATED WEED REMOVAL MACHINE

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Abstract — Weed operation is among the most significant way for agrarian crop product. Herbaceous species contend with crops for nutrients, sun, water and soil coffers which greatly reduces crop yield and productivity. Weed junking is done traditionally by homemade sweats or chemical dressings, both of which have a number of limitations including high labour conditions, time consumption and implicit environmental impact. also, as bedded systems and agrarian robotization technologies further develop, robotic styles have handed promising results in enhancing husbandry systems. In this paper, we present a design and development of semi-automated weed junking machine which can help growers to cover the crop fields efficiently by drawing the weed in effective manner. A bedded control unit with wireless communication and real- time monitoring is used to develop the system. The robot corresponds of the robotic platform, multiple DC gear motors for translational movement stepper motor for cutting medium used for unwanted weed junking in this weeding process above soil face. The motor control circuits, relay switching medium and rechargeable power force can ensure stable operation when the device moves in the field and cuts backwoods. Experimental tests were performed in order to assess the mobility of the robotic platform, cutting capability and effectiveness of operation. The issues show the developed ranch- scale squash weed check approach is able of reducing homemade labour conditions, while also perfecting the effectiveness of organic abdominal weed control compared to assiduity norms. Proposed system can act as a doable and low- cost result feeding to small and medium scale husbandry practices, paving way for robotization technologies in ultramodern day tilling fashion.

Keywords — IoT-Based Agriculture, ESP32-CAM, Weed Removal Robot, Crop Monitoring System.

I. INTRODUCTION

Agriculture is crucial for sustaining the global food system and provides a livelihood for millions of people worldwide. As we know agricultural productivity can be affected by pest infestation, soil conditions, water availability and weed growth. A lot of things can go wrong while growing crops, but one of the most prevalent issues for farmers is weed growth. Weeds compete with crops for nutrients, water and sunlight in the soil and space which can drastically affect both yield and quality of the crops. Conventional methods of weed removal primarily consist of manual labour with handheld tools or

chemical herbicides. In many agricultural regions, manual weeding is commonly done to selectively uproot weeds that do not disturb the crops. Nevertheless, this technique demands a considerable amount of work and hours, especially on extensive crop fields. Moreover, rising labor costs and a shortage of agricultural labourers have made it impractical for many farmers to weed by hand. That is why herbicides also widely used for weeds control as they can be applied quickly to a large area of land. Herbicides, while effective in combating unwanted vegetation, can lead to environmental issues such as soil and water pollution and the harm of local flora/fauna ecosystem. Improper application of herbicides can also kill crops and deplete soil fertility, in the longer term. The development of robotics, embedded systems and wireless communication technologies has opened up new possibilities for improving agricultural practices. Agricultural-related robots that complete repetitive tasks like crop planting, spraying crops, monitoring crops and establishing weed control more efficiently and with fewer human employees. Semi-automated agricultural machines are a viable solution to this by introducing a compromise between an automated mechanical operation and human monitoring. This project aims to design, develop and implement a semi-automated weed removal machine that helps farmers remove weeds more efficiently by reducing the need for labour.

II. LITERATURE SURVEY

Weeds are an inevitable part of crop farming and, as such, it is imperative that appropriate methods are used to manage this agricultural concern to ensure not only crop yield but soil viability. Weeds compete with crops for essential resources, including nutrients, water, sunlight and the growing space they need to thrive something that can drastically impact how much crop yield an area produces if not effectively managed. Weed removal has historically been done through the manual labour ruthlessly with hand tools or more simple mechanical devices. However, manual weed control is time consuming and labour-intensive in large agricultural fields and thus, not efficient. Modern agriculture has also extensively relied on the use of chemical herbicides for weed control. Although herbicide can have rapid action against weeds, overusing chemical methods in controlling weeds may result to pollution in the environment, destruction of soil, affecting human health. These limitations have propelled researchers to look for alternative, more efficient and sustainable weed control methods. Mechanical weeders have come online as a

chemical-herbicide-free alternative in an attempt to reduce dependence on this class of pesticide. These systems rely on mechanical cutting or uprooting mechanisms that remove the weeds from the soil surface. However, most conventional mechanical weeders are non-selective and may cause damage to nearby crops during weeding operation. Studies in the field of controlled weed eradication have indicated that plant management procedures are more precise and effective when performed by robotic platforms [1]. Some of these modern machines are also used in irrigation, spraying or treatment, planting and harvesting. Agricultural robots consist of mechanical components along with sensors and embedded control systems for performing repetitive tasks with higher precision than manual methods [2]. These systems assist in optimising labour requirements and enhancing operational efficiency in farming activities.

Weed detection and classification have also been studied using different methods in vision-based and intelligent agricultural systems. Machine learning and deep learning algorithms have been used with various image processing technique for crop and weed classification.

This allows for the targeted removal of weeds in precision agriculture [3]. That being said, embedded controllers as well as sensors and wireless communication technologies have certainly added functionality to modern machines designed for agriculture. This versatility enhances field operation efficiency by enabling the use of smart robotic systems integrated with microcontrollers and communication modules to monitor and control agricultural equipment remotely [5].

III. COMPONENTS

The major components of the developed system include:

- ESP32-CAM module – WiFi communication and camera capable embedded controller.
- L293D motor driver IC – It is a Motor Driver which can control DC Motors.
- DC Gear Motors – Moves the robotic platform.
- Relay Module – This controls the Motor Blade that cuts the weeds.
- Blade Motor & Cutting Blade – Mechanical weed removal
- Battery – Powers the whole system.
- Chassis and wheels – Give mechanical structure to the robot.

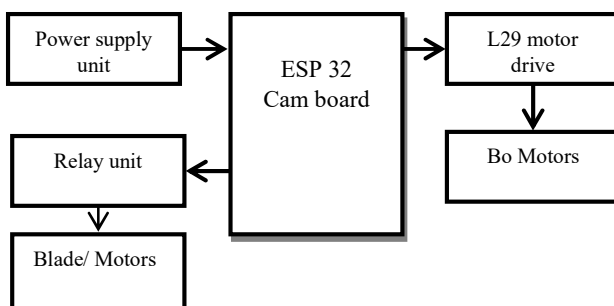


Fig No 1: Structure layout

IV. METHODOOGY

The methodology details the design, development and method of operation of the semi-automated weed removal machine. The system was built to help farmers eliminate weeds effectively with less manual work and processing time. In this proposed system, mechanical components and embedded electronics were integrated with communication to perform weed cutting operations in agricultural fields. Initially, a compact robotic platform was designed and developed for travelling over agricultural soil surfaces. The most important part of the project is its platform which includes a chassis to hold all major components like controller unit, motor driver module, relay and motors & supporting power supply. The chassis structure can lift up the robot and provides mechanical stability for smooth, time-competitive transition through agricultural terrain. As the core controller for the system is the microcontroller module. This controller receives commands, processes control signals and manages the movement of the robotic platform as a central processing unit within the machine. The controller interacts with the electronic components, including motor driver and relay module to carry out operations. To move, the system employs DC gear motors that are coupled to a designed robotic wheel platform. The motors provide the torque needed to carry the robot over the agriculture field. A motor driver module is used to control motors, so that the microcontroller can control direction of rotation and motion of the robot. The system can move forward, backward as well as left and right by controlling the motor driver inputs. The weed cutting mechanism is a rotating blade that has been fitted underneath the robotic chassis. When powered up, the centrifugal motor is responsible for spinning the blade at high speed. The blade motor controls through a relay module, or the effectively operate switch. The relay is turned on by the controller control signal, which gives power to turn on the switch of the blade motor; thus, rotating cutting edge from started weeds and removing from soil surface. Thus, wireless communication is a key aspect of the functioning of the system. In honor of the controller, it has WiFi capability and enables a remote-control robot through a web interface. A simple web-based control interface let the user send movement commands to the robot from a mobile phone or computer. This enables the operator to navigate the robot over the field while observing its movement. The whole system receives commands from the user end to an actuator that gets processed via automatic controller. Depending on the command received, the controller activates the motor driver for motion or switches on the relay module to operate the cutting blade. When it moves through the field, the rotating blade slices and pulls weeds from top soil. This approach provides a simple but efficient method for semi-automated weed removal. The machine integrates cutting with remote operational capacity to lessen the quiet reflection in the agriculture sector and heighten working proficiency.

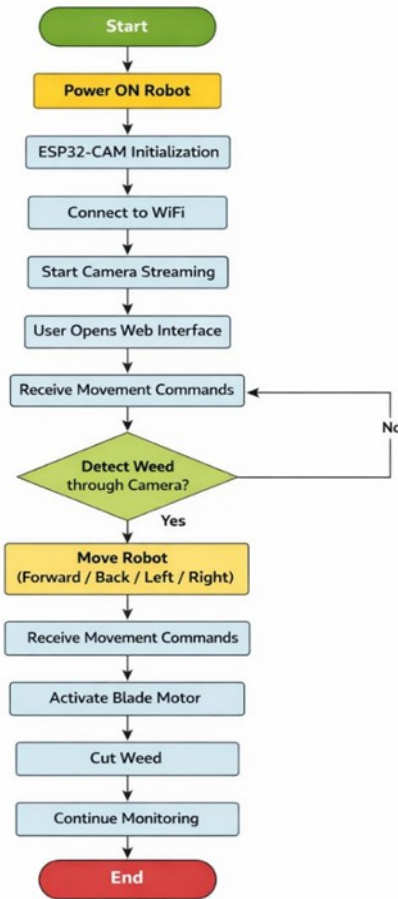


Fig No 2: Process flow chart

V. WORKING PRINCIPLE

The operation of the semi-automated weed removal machine is achieved by combining a control system based on microcontrollers with mechanics for cutting and mobile robotics. The system helps the farmers to get rid of the weeds in effective manner which saves manual effort in agriculture fields. On powering the system through rechargeable battery supply, working process starts. After powering the IGVC electronics, the microcontroller module boots and connects to WiFi; this lets you control your robot via a web interface. A mobile phone or computer that shares the same local area network can be used by the user to access control and interface. The user provides some instructions to move forward, backward, left and right through the web interface. The controller module receives these commands, processes the signals and sends control signals to the motor drive circuit. This signals the DC gear motors, which are connected to the wheels of a robotic platform via a motor driver circuit that can move in different directions across an agricultural field. The weed has been removed through a rotating cutting blade which is located below the bottom of the robot. The blade is associated with a separate motor that is controlled by means of relay module. The controller sends an ON signal to the relay module when the user calls for cutting operation in the control interface. The relay then powers on the blade motor, which rotates the cutting blade at high speed. When the robot travels forward in the field, rotating blade cuts weeds from the soil

surface. The robot cuts through unwanted plants, minimizing the interference in its movement. The system controller also stops the blade motor when cutting is not needed anymore by interrogating relay module. With the wireless control of movement and motor-driven phase, the arrangement can perform semi-automatic weed removing measures. In turn, this makes manual weed removal more efficient as it lessens the physical effort needed to cover larger areas quickly.

VI. HARDWARE INTERFACING PIN CONFIGURATION

Hardware assembly and interfacing is a key development phase for the semi-automated weed removal machine, as this phase allows communication between different electronic coordinates throughout the process. This project is controlled using ESP32-CAM module, controlling motors, relay module or more peripherals. Introduction ESP32-CAM has 3 to 5 Multiple General Purpose Input Output (GPIO) pins which is used to interface with external components kin of Motor driver and relay module by ESP32. Thus, we must configure these pins correctly to ensure the accurate control of the robotic platform and weed cutting device.

ESP32-CAM pin	Connection	Function
GPIO12	Motor Driver IN1	Control Left Motor Direction
GPIO13	Motor Driver IN2	Control Left Motor Direction
GPIO14	Motor Driver IN3	Control Right Motor Direction
GPIO15	Motor Driver IN4	Control Right Motor Direction
GPIO2	Relay Module	Control Blade motor
5V	Power Supply	Provide Operate Voltage
GND	Ground	Ground connection

Table No 1: ESP32 Connection

VII. PROTOTYPE

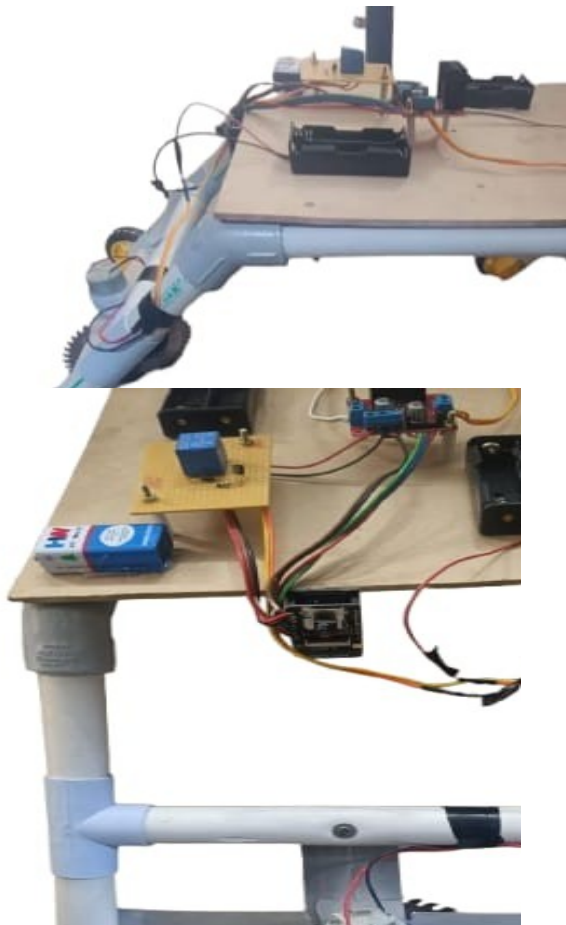


Fig No 3: Proposed model

IX. BLADE CUTTING FORCE CALCULATION

S.No	Parameter / Component	Formula / Specification	Value
1	Blade Motor Speed	Given motor speed	1000 RPM
2	Angular Velocity	$\omega = (2\pi N)/60$	104.7198
3	Angular Velocity Value	ω	104.72 rad/s
4	Motor Power	Assumed small DC motor power	50 W
5	Torque Produced by Motor	$T = P / \omega$	0.477464
6	Torque Value	T	0.477 Nm
7	Blade Radius	Average blade radius	0.05 m
8	Cutting Force	$F = T / r$	9.54

Table No 2: Blade cutting force calculation

X. BATTERY RUN TIME CALCULATION

S.No	Parameter / Component	Formula / Specification	Value
1	Motor Speed	Blade motor speed specification	1000 RPM
2	Wheel Drive Motors	6 DC gear motors used for robot movement	12 V motors
3	Battery Capacity	One Li-ion battery = 4800 mAh	4.8 Ah
4	Total Battery Capacity	4 batteries \times 4.8 Ah	19.2 Ah
5	Battery Capacity for Drive System	2×4.8 Ah	9.6 Ah
6	Battery Capacity for Blade Motor	2×4.8 Ah	9.6 Ah
7	Current Consumption (Drive Motors)	Assumed average current	3 A
8	Current Consumption (Blade Motor)	Motor current requirement	2 A
9	Runtime of Drive System	$T = C / I = 9.6 / 3$	3.2 hours
10	Runtime of Blade Motor	$T = C / I = 9.6 / 2$	4.8 hours

Table No 3: Battery run time calculation

VIII. SOFTWARE IMPLEMENTATION

Software Implementation of the System, The code specified to compile a control program for the ESP32-CAM microcontroller. The software facilitates user-robot communication, command parsing and hardware control. In this project, the program is written in Arduino IDE. This is embedded C/C++ supported by the Arduino platform. Our software initializes the hardware components, connect to Wi-Fi, controls motor movement, triggers the blade motor using a relay module as well as sending live video over via camera module.

```

Motor_Control_Code | Arduino
File Edit Sketch Tools Help
Motor_Control_Code
// Motor Control Code
define IN1 12
define IN2 13
define IN3 14
define IN4 15

void setup() {
  pinMode(IN1, OUTPUT);
  pinMode(IN2, OUTPUT);
  pinMode(IN3, OUTPUT);
  pinMode(IN4, OUTPUT);
}
    
```

Fig No 4: Software description

XI. RESULT AND DISCUSSION

A tracked semi-automated weeder was tested under controlled field conditions to assess its ability to maneuver as well as its effectiveness and efficiency at cutting weeds. We tested this on a small agricultural plot with moderate density of weeds. The purpose of this testing was to see how optimally the machine could travel around the field and remove weeds through use of its rotatable blades. The robotic platform stayed stable and in control while moving across the soil surface in the experiment. The DC gear motors had enough torque to try and move the robot along the field without too much hassle. The motor driver worked perfectly to drive the wheels according to commands from the controller module. The system allowed the operator to guide the machine across the testing area by maneuvering all available degrees of freedom both forward and backward, as well as a left/right directional change. The relay module was used to activate the weed cutting mechanism that powered on the blade motor. Upon activation, a high-speed cutting blade rotated, which removed high-grown weeds present in the top soil layer. The weeds were successfully cut by the rotating blade of a moving forward robot without restricting the motion of the machine. In addition, the wireless control system operated reliably when tested. We could send commands from the web interface to the controller and it would receive them and execute them without any appreciable delay. That enabled the user to remotely manage the robot's movement and cutting operation. This was to estimate the efficacy of the system in an environment where comparable sector areas were demarcated for mechanised by manual and robotic weeding. Results showcased the effectiveness of the robotic system, precisely reducing both time needed for weed removal and physical labour effort. Though manual weeding may be more accurate in certain scenarios, the robotic system has a potential to aid farmers in being more resourceful when embarking on repetitive weed removal. This means that, based on the total results in trials, this machine can perform semi-automated weed removal operations (in small agricultural fields). Steering machine operated by motors, electric signal transmitter and large area agricultural generalizers.

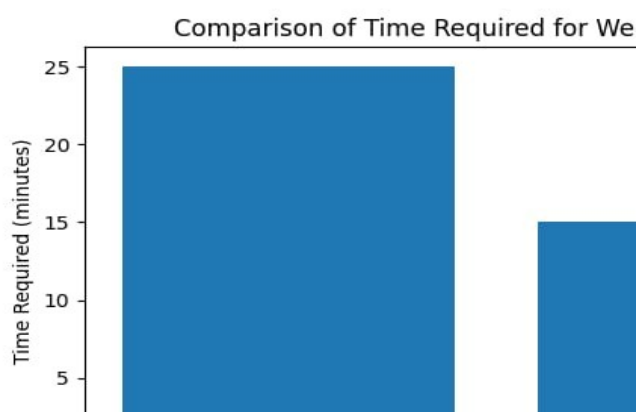


Fig No 5: Comparison chart

XII. CONCLUSION

Model of Weed Remover, The semi-automated weed removal machine design shows the implementation of current technology such as robots in agricultural weeds remotion.

Weed removal with less human intervention. Through control unit, motor driver to the DC gear motors and rotating blade cutting mechanism has been implemented by servo with compact design using microcontroller inbuilt components. In terms of field testing, observations confirm that the machine is able to traverse across the field and kill weeds via controlled cutting while being managed through a wireless interface. All using the system which helps reduce labour dependency and improve operational efficiency compared to conventional weeding methods. wooden barrel, a sharp knife and a motor; that is all it takes to create this delectable cupboard-sized slice of the Atlas Alishan. The system can be further enhanced using various technologies like: automatic weed detection with image processing and AI, better cutting mechanisms to cut different types of weeds and other sensors for obstacle detection and navigation. Such improvements could further convert the system into an intelligent and fully autonomous farm machine that can execute efficient weed control in huge farming fields.

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