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Full Length Article

Design and Implementation of a Smart Agricultural Robot Bulldog (SARDOG)

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Abstract
Agriculture faces critical challenges such as labor shortages, water scarcity, and rising operational costs. To address these issues, this paper presents the design and implementation of a Smart Agricultural Robot Bulldog (SARDOG), an autonomous robotic system integrated with Internet of Things (IoT) technologies and advanced sensing mechanisms. The proposed system utilizes LiDARbased navigation, environmental sensors, and a robotic arm to perform multiple agricultural tasks such as soil analysis, crop monitoring, fruit picking, and automated irrigation. SARDOG aims to improve productivity, reduce manual labor, and enable precision farming through real-time data acquisition and intelligent decision-making.

Keywords: *Smart Agriculture, IoT, Robotics, Embedded Systems, Soil Monitoring, Autonomous Navigation*

Introduction

Agriculture is a vital sector, particularly in countries like India where it forms the backbone of the economy. However, modern agriculture is challenged by labor shortages, inefficient resource utilization, and lack of real-time monitoring. Automation and robotics have emerged as promising solutions to enhance agricultural productivity.

Traditional farming methods rely heavily on manual labor and basic machinery, which are often inefficient and time-consuming. Recent advancements in robotics and IoT technologies provide opportunities to develop intelligent systems capable of performing complex agricultural tasks autonomously.

This paper proposes SARDOG, a smart agricultural robot designed to perform multiple farming operations efficiently using embedded systems, sensors, and IoT-based communication.

Literature Review / Existing System

Existing agricultural systems mainly rely on manual labor, conventional farming machinery, and limited automation tools for carrying out agricultural activities. Farmers traditionally perform tasks such as irrigation, crop monitoring, harvesting, and soil management manually, which often requires significant human effort and time. Although conventional machinery has improved productivity to some extent, most existing systems still lack advanced automation and intelligent decision-making capabilities. These systems face several limitations, including high labor dependency, inefficient crop monitoring methods, limited versatility in performing multiple agricultural operations, and poor utilization of data for informed decision-making. As a result, farming operations may become less efficient, costly, and difficult to manage on a large scale.

Proposed System

The proposed **SARDOG system** is designed to overcome the limitations of traditional agricultural methods by integrating robotics, Internet of Things (IoT), and embedded system technologies to automate agricultural operations. The system incorporates autonomous navigation using LiDAR technology for obstacle detection and path planning, enabling efficient movement within agricultural fields. It also includes soil moisture and environmental monitoring sensors to collect real-time field data for better crop management. A robotic arm is integrated for automated fruit-picking operations, while an intelligent irrigation system ensures efficient water usage based on sensor readings. Additionally, the system features a farmer-following capability that allows the robot to assist farmers during field activities. Through IoT-based communication, real-time monitoring and data analysis are enabled, allowing farmers to make faster and more informed decisions. The proposed

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system offers several advantages, such as reduced labor dependency, enhanced precision and operational efficiency, cost-effective farming practices, and improved real-time decision-making capabilities.

System Architecture

Embedded System Overview

The SARDOG system is developed using an embedded system architecture that combines hardware and software components to perform automated agricultural tasks efficiently. The core of the system is the **Raspberry Pi Pico W microcontroller**, which controls and coordinates the operation of sensors, actuators, and communication modules. Various sensors are integrated to monitor environmental conditions, soil moisture levels, and navigation parameters, while actuators enable mechanical operations such as robotic arm movement and irrigation control. Communication interfaces facilitate data exchange between the embedded system and IoT platforms for remote monitoring and control. A reliable power supply system is incorporated to ensure continuous and stable operation of all system components, enabling the SARDOG system to function effectively in agricultural environments.

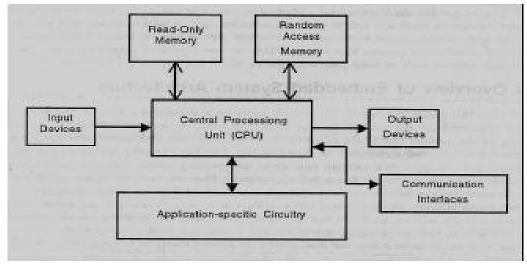
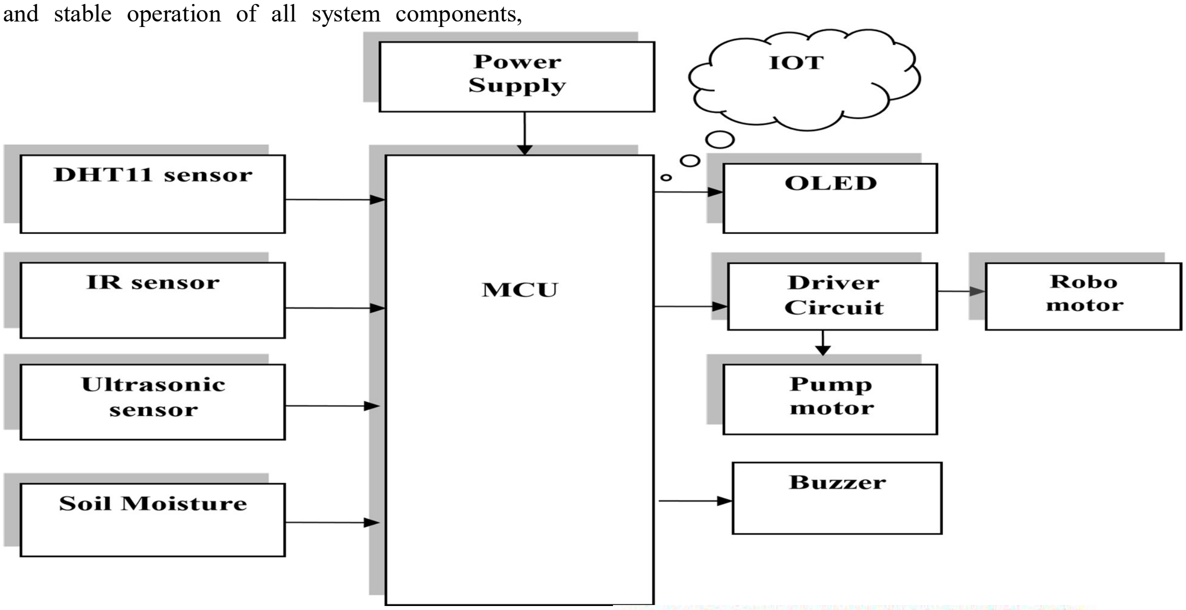


Fig 1; Block Diagram Components

Microcontroller Unit (MCU)
Power Supply
Ultrasonic Sensor
Soil Moisture Sensor
DHT11 Temperature Sensor
IR Sensor
OLED Display
IoT Module
Pump Motor & Relay
Driver Circuit (ULN2003)



Hardware Components

Microcontroller (Raspberry Pi Pico W)
Dual-core ARM Cortex-M0+ processor
Built-in Wi-Fi and Bluetooth
264KB SRAM and 2MB Flash
Supports IoT communication

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Fig 2; Sensors

DHT11 Sensor: Measures temperature and humidity

The DHT11 is a commonly used Temperature and humidity sensor. The sensor comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data. The sensor is also factory calibrated and hence easy to interface with other microcontrollers.

The sensor can measure temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy of ±1°C and ±1%. So if you are looking to measure in this range then this sensor might be the right choice for you.

DHT11 Specifications:

Operating Voltage: 3.5V to 5.5V

Operating current: 0.3mA (measuring) 60uA (standby)

Output: Serial data

Temperature Range: 0°C to 50°C

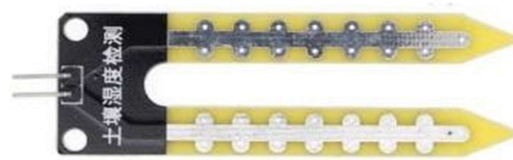
Humidity Range: 20% to 90%

Resolution: Temperature and Humidity both are 16-bit

Accuracy: ±1°C and ±1%

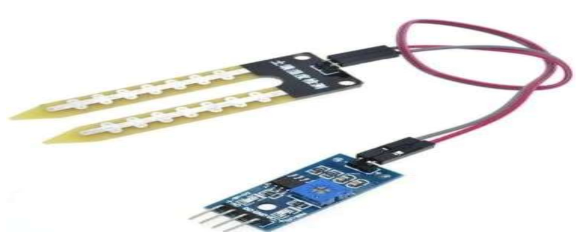
Soil Moisture Sensor: Detects water content in soil

A soil moisture sensor is a type of sensor used to measure the volumetric water content of the soil. Because, a direct gravimetric amount of soil moisture must be removed, dried and weighed. These sensors do not directly measure volumetric water content using other soil laws such as permittivity, electrical resistivity, interaction with s, and water content displacement.



SPECIFICATIONS:

SENSOR TYPE	SOIL MOISTURE SENSOR
Operating Voltage	3.3V- 5V
Current flow	<20 Am
Type of interface	Analog Type
Working temperature of the sensor	10 – 30 degree Celcius
PCB dimension of comparator	3 cm x 1.5 cm
Soil Probe Dimension	6 cm x 3 cm
Cable Length	20 cm
Weight	50 gms



+	Voltage Supply
-	-ve pin
LM393 Comparator	
VCC	Power supply
Gnd	Common GND
AO	Analog pin
DO	Digital pin

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Ultrasonic Sensor: Measures distance for obstacle detection

Ultrasonic sensors are industrial control devices that use sound waves above 20,000 Hz, beyond the range of human hearing, to measure and calculate distance from the sensor to a specified target object.

Features of ultrasonic sensors:

- ✦ Devices with TEACH-IN functionality for fast and simple installation
- ✦ ULTRA 3000 software for improved adaptation of sensors to applications
- ✦ Adjustable sensitivity to the sound beam width for optimized adjustment of the sensor characteristics according to the application
- ✦ Temperature compensation - compensates for sound velocity due to varying air temperatures
- ✦ Synchronization input to prevent cross-talk interference when sensors are mounted within close proximity of each other
- ✦ Sensors with digital and/ or analog outputs

IR Sensor: Detects nearby objects

IR sensor is very useful if you are trying to make a obstacle avoider robot or a line follower. In this project we are going to make a simple IR sensor which can detect a object around 6-7 cm. IR sensor is nothing but a diode, which is sensitive for infrared radiation. This infrared transmitter and receiver is called as IR TX-RX pair.

Fig. IR Sensor

FEATURES

Fast response time

Because it have good range which is fulfill our requirements.

It is very low cost and can be constructed on general purpose.

It is of very small size.

You can increase numbers of transmitter as you want for good result

Good immunity to ambient light and waves are invisible to eyes.

Actuators

Water pump for irrigation

This submersible pump is designed for reliability and ultra-quiet operation to provide years of service. The small profile size makes the pump easy to hide or disguise. Has adjustable flow and is easy to clean. This submersible water pump is great for aquarium, fountains, spout and hydroponic systems.

FEATURE:

Adjustable water flow rate

Suction cup mounting feet for either vertical or horizontal mounting

Contains no seals or messy oils ➢ Good for both fresh water and salt water

SPECIFICATION:

Max Flow Rate: 20L/H

H-Max (Lift height): 1.6 feet

Power: 6-18 Watt

Voltage: 110 – 120/230 V @ 50 Hz

Outlet: Fits 0.315" ID (inside diameter) tubing

INCLUDES:

(1) Pump

(1) Outlet adapter

DC motor

A DC motor in simple words is a device that converts direct current(electrical energy) into mechanical energy. It's of vital importance for the industry today.

A DC motor is designed to run on DC electric power. Two examples of pure DC designs are Michael Faraday's homo-polar motor (which is uncommon), and the ball bearing motor, which is (so far) a novelty.

We in our project are using brushed DC Motor, which will operate in the ratings of 12v DC 0.6A.

The speed of a DC motor can be controlled by changing the voltage applied to the armature or by changing the field current. The introduction of variable resistance in the armature circuit or field circuit allowed speed control. Modern DC motors are often controlled by power electronics systems called DC drives.

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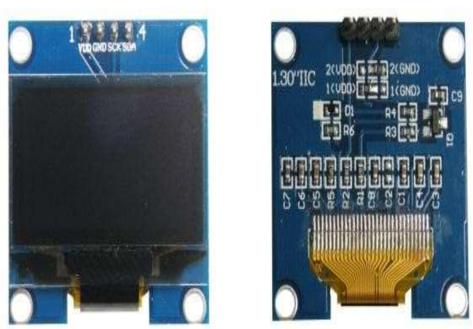
Relay for high-power switching relay is an electromechanical switch, which perform ON and OFF operations without any human interaction. General representation of double contact relay is shown in fig. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

Fig. Relay

Display

OLED display for real-time data visualization

OLED (Organic Light Emitting Diodes) is a flat light emitting technology, made by placing a series of organic thin films between two conductors. When electrical current is applied, a bright light is emitted. OLEDs are emissive displays that do not require a backlight and so are thinner and more efficient than LCD displays (which do require a white backlight). OLED displays are not just thin and efficient - they provide the best image quality ever and they can also be made transparent, flexible, foldable and even rollable and stretchable in the future. OLEDs represent the future of display technology!

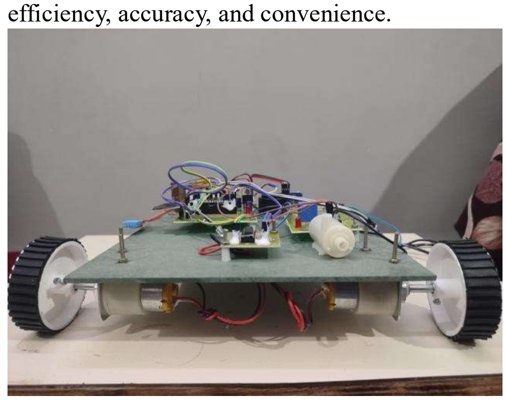


Software Implementation

The software implementation of the **SARDOG** system is carried out using development platforms such as **Arduino IDE** along with programming languages like **Embedded C** and **MicroPython**. These software tools provide the necessary environment for programming and controlling the embedded components of the system. The implemented software is responsible for several critical functions, including sensor data acquisition, decision-making processes, IoT communication, and motor control operations. Sensor data acquisition enables the continuous collection of information from soil moisture, temperature, distance, and environmental sensors. Decision-making algorithms process the collected data and determine appropriate actions based on predefined conditions. The software also manages IoT-based data transmission, allowing real-time monitoring and communication between the robot and remote users. Additionally, motor and actuator control functions regulate the movement of the robot, operation of the robotic arm, and activation of the irrigation system, ensuring smooth and automated functioning of the agricultural robot.

Working Principle

The working principle of the **Smart Agricultural Robot Bulldog (SARDOG)** is based on continuous sensing, data processing, and autonomous decision-making. The robot continuously gathers information from multiple sensors, including soil moisture sensors, temperature sensors, and distance sensors, to monitor agricultural field conditions. Based on the received sensor inputs, the system performs appropriate actions automatically. When the soil moisture level falls below a predefined threshold, the irrigation system is activated to supply the required amount of water to crops. If obstacles are detected during movement, the robot adjusts its navigation path using obstacle detection and avoidance mechanisms to ensure safe operation within the field. Simultaneously, environmental and operational data are transmitted through IoT communication modules, enabling real-time remote monitoring and analysis by farmers or users. Through this intelligent workflow, the system operates autonomously while also allowing remote supervision and control, thereby improving farming efficiency, accuracy, and convenience.



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Results and Discussion

The implemented **SARDOG** system demonstrates effective performance in automating various agricultural operations. The system successfully performs efficient soil monitoring by continuously collecting and analyzing soil moisture and environmental data, allowing better crop management practices. The automated irrigation mechanism operates based on real-time sensor readings, ensuring optimal water utilization and reducing water wastage. The integration of LiDAR technology enables reliable obstacle detection and autonomous navigation, allowing the robot to move safely and efficiently within agricultural fields. In addition, the system supports real-time data communication through IoT connectivity, enabling remote monitoring and control of agricultural activities. The integration of IoT technologies significantly enhances decision-making capabilities by providing farmers with timely and accurate field information, thereby improving overall farming efficiency and productivity.

Applications

The Smart Agricultural Robot Bulldog (SARDOG) has wide-ranging applications in modern agricultural environments. It can be effectively used in **smart farming** to automate routine agricultural tasks and improve farm management efficiency. In **precision agriculture**, the system supports accurate monitoring and resource management through real-time data collection and analysis. The robot is also suitable for **crop monitoring**, where environmental and soil conditions are continuously observed to ensure healthy crop growth. Its automated irrigation functionality makes it valuable for **automated irrigation systems**, helping farmers optimize water usage. Furthermore, the system can serve as a useful platform for **agricultural research**, enabling researchers to study advanced agricultural automation technologies and develop innovative farming solutions.

Conclusion

The **Smart Agricultural Robot Bulldog (SARDOG)** presents an intelligent and efficient solution for addressing the challenges of modern agriculture. By integrating IoT technology, embedded systems, and robotics, the system minimizes manual labor requirements while enhancing agricultural productivity and operational efficiency. The proposed system demonstrates the growing potential of automation in transforming traditional farming practices into smarter and more sustainable agricultural methods. Through features such as autonomous navigation, environmental monitoring, automated irrigation, and real-time communication, SARDOG contributes to improved resource management and decision-making. In the future, the system can be further enhanced by incorporating Artificial Intelligence (AI) and Machine Learning (ML) techniques to enable predictive farming, advanced analytics, and more adaptive agricultural automation capabilities.

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