CSE360: Computer Interfacing

Project Report

PlantPal

[Automated Irrigation Robot]

Spring 2024

Introduction:

Modern agriculture is increasingly adopting smart technologies to improve efficiency and sustainability. The project presented here focuses on the implementation of a Automated Irrigation Robot using a combination of Ultrasonic, Soil Moisture, and Water Level sensors along with Arduino (*Arduino Docs | Arduino Documentation*, n.d.) and Raspberry Pi (*Raspberry Pi Documentation*, n.d.) platforms. This innovative system aims to optimize irrigation practices by automating the process based on real-time environmental data and plant-specific requirements. The system begins with plant detection using machine learning algorithms and a Pi camera. Upon identifying a plant, a robotic platform equipped with an ultrasonic sensor navigates towards it. Raspberry Pi calculates and positions a robotic arm for tasks like watering based on the plant's location. Arduino monitors soil moisture levels and communicates with Raspberry Pi to decide if irrigation is needed. If necessary, Arduino controls a motorized irrigation system. Additionally, Arduino tracks water levels, alerting when they are low. This system ensures efficient irrigation by continuously assessing soil moisture levels and optimizing water usage based on plant requirements. It represents a practical application of smart technology in agriculture to enhance productivity while conserving resources.

Application Area:

1. **Urban Farming:**
   - Enabling efficient water management for rooftop gardens and small-scale agriculture.
2. **School or Educational Gardens:**
   - Implement a hands-on learning experience for students about water conservation and plant care.
   - Showcase sustainable technologies in action for educational purposes.
   - Ensure that the garden thrives even during school holidays or breaks.
3. **Greenhouse or Indoor Growing Setup:**
   - Control irrigation for indoor crops or hydroponic systems.
   - Ensure precise moisture levels for different plant species grown indoors.

Equipments/ Tools Used:

1. Raspberry Pi
2. Pi Camera
3. Ultrasonic Sensor
4. Servo Motor
5. DC Geared Motor
6. Arduino UNO
7. Soil Moisture Sensor
8. Water level sensor
9. Passive Buzzer
10. 16x2 Serial LCD Display with I2C Module
11. Wire
12. Breadboard

Sensors:

In this project we use four sensors. They are Ultrasonic sensor, Soil Moisture sensor, Water Level sensor, and RPi Camera Sensor.

- **Ultrasonic**

  Function: Ultrasonic (*7. Ultrasonic Distance Sensor — Smarthon Documentation 1.0 Documentation*, n.d.) sensors utilize sound waves with frequencies higher than the human audible range to measure distances to nearby objects.

  Working Principle: The sensor emits ultrasonic waves and then listens for the waves to bounce back after hitting an object. By calculating the time it takes for the waves to return, the sensor can determine the distance to the object.

  Applications: Ultrasonic sensors are commonly used in robotics, automation, parking assistance systems, and proximity detection.

- **Soil Moisture**

  Function: Soil moisture (*How Does a Soil Moisture Sensor Work and How to Use It with Arduino?*, n.d.) sensors measure the water content in soil, which is crucial for efficient irrigation and agricultural management.

Working Principle: These sensors typically utilize either resistive or capacitive principles. Resistive sensors measure the electrical resistance between two electrodes, which changes with soil moisture content. Capacitive sensors measure the dielectric constant of the soil, which varies with moisture content.

Applications: Soil moisture sensors are extensively used in agriculture, gardening, and environmental monitoring to optimize water usage and ensure proper plant growth.

- **Water Level**

  Function: Water level (*How Does a Water Level Sensor Work and How to Interface It with Arduino?*, n.d.) sensors detect the depth or height of water in a container, reservoir, or other water bodies.

  Working Principle: Different types of water level sensors exist, including float switches, pressure sensors, and capacitive sensors. Float switches consist of a buoyant float attached to a lever, which actuates a switch as the water level changes. Pressure sensors measure the pressure exerted by the water column above them. Capacitive sensors detect the presence of water by measuring changes in capacitance.

  Applications: Water level sensors are used in various applications such as sump pumps, aquariums, water tanks, and industrial processes to monitor and control water levels, preventing overflow or depletion.

- **RPi Camera Sensor**

  Function: The Raspberry Pi camera sensor serves as a fundamental component in digital imaging devices, facilitating the conversion of incident light into electronic signals crucial for capturing images or video.

  Working Principle: Leveraging the principle of photoelectric conversion, the Raspberry Pi camera sensor comprises an array of photosensitive pixels. When exposed to light, these pixels generate electrical signals in proportion to the intensity of the incident light. These signals undergo processing to generate a digital representation of the captured scene.

  Applications: The Raspberry Pi camera sensor is widely utilized in photography, videography, surveillance, medical imaging, automotive safety, and smartphone cameras. Its compact size and versatility enable enthusiasts, hobbyists, educators, and professionals to innovate in digital imaging.

Circuit Diagram:

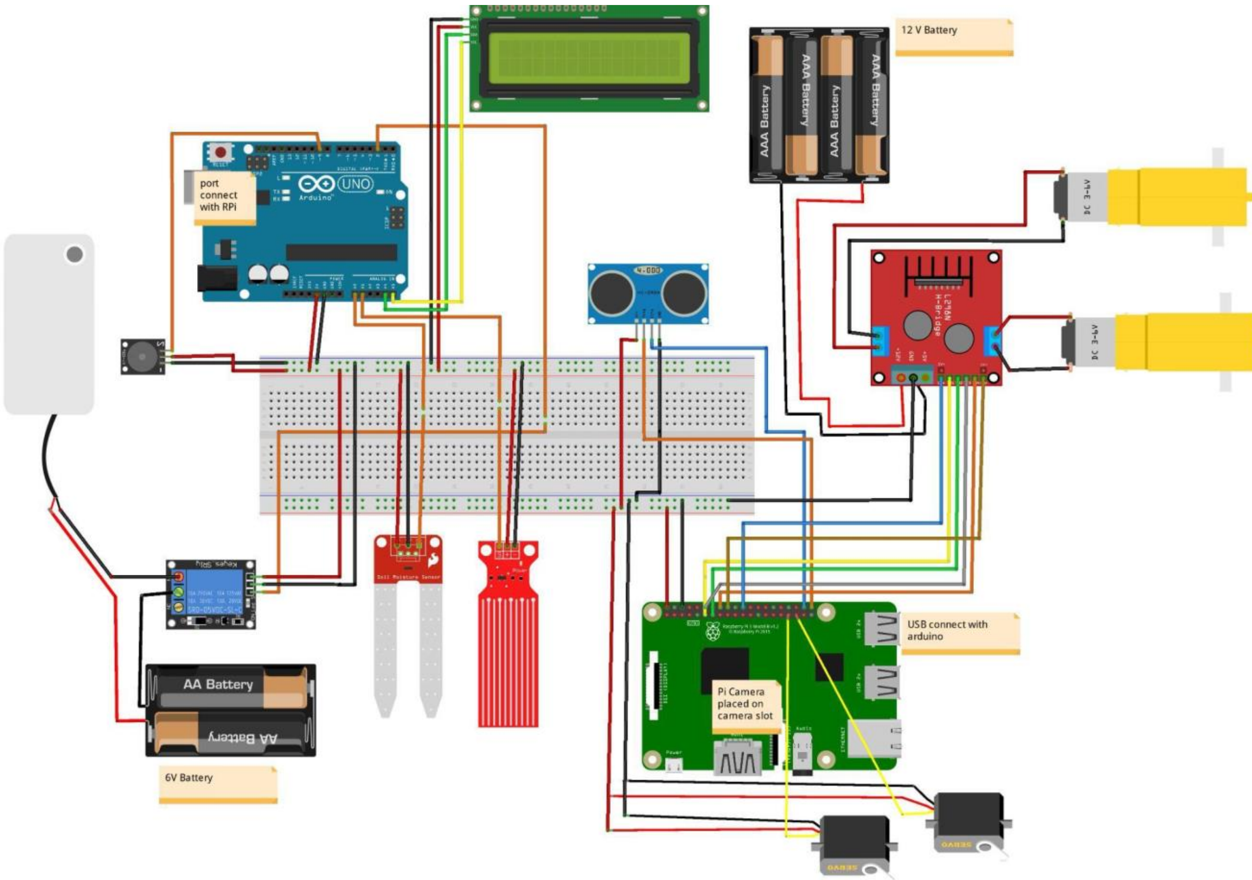

Fig: Automated Irrigation Robot Circuit Design

Protocols (SPI, I2C, UART):

Arduino and Raspberry Pi Communication:

The interaction between the Raspberry Pi and Arduino is facilitated through UART (Universal Asynchronous Receiver-Transmitter) serial communication. In the Python script running on the Raspberry Pi, a serial connection is established with the Arduino board via the /dev/ttyACM0 port at a baud rate of 9600. This allows the Raspberry Pi to send commands and receive data from the Arduino to control the irrigation system based on soil moisture readings.

Ultrasonic Sensor Integration:

The ultrasonic sensor, used for detecting distances between the robotic system and plants, interfaces directly with the Raspberry Pi using GPIO (General Purpose Input/Output) pins. GPIO pins TRIG and ECHO are configured to trigger and capture the echo response of ultrasonic pulses, enabling the Raspberry Pi to calculate distances accurately.

Analog Sensor Readings (Soil Moisture and Water Level):

The Arduino board is responsible for interfacing with analog sensors such as the soil moisture sensor and water level sensor. These sensors provide analog output signals proportional to the soil moisture and water levels, respectively. The Arduino reads these analog signals using its built-in Analog-to-Digital Converter (ADC), converting the analog readings into digital values that can be processed and transmitted to the Raspberry Pi.

Object Detection with Pi Camera:

The Raspberry Pi utilizes the Pi camera module along with OpenCV (Open Source Computer Vision Library) (*OpenCV: Object Detection*, n.d.) for object detection and recognition. The Python script employs computer vision algorithms to analyze video frames captured by the Pi camera in real-time. This allows the system to detect specific objects of interest, such as potted-plants, based on pre-trained models and image processing techniques.

Estimated Cost Analysis:

Item name	Cost (tk)
Raspberry Pi	12,000
Pi Camera	880
Ultrasonic Sensor	93
Arduino UNO	1,010
Soil Moisture Sensor	280
Watering level sensor	350
Passive Buzzer	49
16x2 Serial LCD Display with I2C Module	340

Jumper Wires	60
Breadboard	160
Water pump	150
Servo Motors	180
DC Geared Motors	170
Wheels	150
Relay Switch	75
Other materials	350
	Total 15,287 tk

Project Workings:

The working procedure for our automated irrigation robot is as follows:

1. **Plant Detection:**

Utilize a Machine Learning model along with a Pi camera to detect potted plants in the surroundings. The ML model identifies the presence and location of plants based on image analysis.

2. **Robot Movement:**

The robot, equipped with wheels and an ultrasonic sensor, moves towards the detected plant's direction. The ultrasonic sensor helps in determining the distance between the robot and the plant for precise movement.

3. **Robotic Arm Positioning:**

Once the robot reaches the plant, Raspberry Pi calculates and sets the position of the robotic arm for tasks such as watering or pruning.

4. **Soil Moisture Sensing:**

Arduino, integrated with a soil moisture sensor, collects data on the soil's moisture level. The moisture sensor provides real-time feedback on the soil's hydration status.

5. **Decision Making:**

Raspberry Pi processes the soil moisture data and compares it with a predefined threshold to determine if irrigation is necessary. Based on the threshold, Raspberry Pi decides whether to proceed with watering or not.

6. **Watering Mechanism:**

Upon decision-making, Raspberry Pi communicates with Arduino to initiate the watering process. Arduino controls a motorized mechanism to irrigate water into the soil based on the instructions received from Raspberry Pi.

7. **Water Level Monitoring:**

Arduino continuously monitors the water level in the robot's water pot to ensure it is sufficient for irrigation. If the water level drops below a certain threshold, Arduino activates a beep sound to alert about the low water level.

8. **Feedback Loop:**

After watering, Raspberry Pi checks the soil moisture level again to ensure proper hydration. If the soil moisture level reaches the desired threshold, Raspberry Pi signals Arduino to stop irrigation.

Conclusion:

In conclusion, the implementation of this Automated Irrigation Robot exemplifies the potential of integrating sensor technology and robotics in agriculture. By automating irrigation based on real-time data from soil moisture, potted plant detection, and water level sensors, the system optimizes water usage while ensuring plants receive adequate hydration. The use of machine learning for plant detection and Raspberry Pi for decision-making underscores the versatility and intelligence of the system. This project not only enhances agricultural productivity but also promotes sustainability by minimizing water wastage and labor-intensive manual irrigation practices. Moving forward, further enhancements and scalability can be explored to adapt this system for different crops and farming environments. The combination of hardware and software components showcased in this project serves as a foundation for future innovations in smart agriculture, contributing to more efficient and eco-friendly farming practices.

Reference:

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