ECE198 Project Proposal

Plant Monitoring System Using STM32 Microcontrollers

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Project Overview

The project involves developing a plant monitoring system aimed at home gardeners. The system will utilize sensors to provide real-time data on soil moisture and soil temperature, two critical factors affecting overall plant health. By continuously monitoring these parameters, the system will display and alert the plant owner of any necessary interventions, including but not limited to; additional watering, increasing sunlight exposure, increasing/decreasing room temperature etc. This system will simplify plant care and increase overall plant survival and growth rates.

The primary STM32 microcontroller will be programmed to perform continuous data acquisition from the connected sensors. It will evaluate the moisture and temperature data, implementing algorithms that determine whether the environmental conditions are within the preset parameters for optimal plant growth. The secondary microcontroller will manage the alert system, triggering visual notifications on the system's LCD display.

Customer Problem

The primary customers for this system are residential gardeners who either practice indoor or outdoor gardening. This includes individuals in urban and suburban settings who are engaged in gardening as a hobby or for home food production. The target market size is estimated to be around 50,000 individuals, based on market trends that indicate a rise in home gardening activities. This system is centred on the difficulties residential gardeners face in consistently maintaining the optimal growth conditions for their plants. The primary issues include managing environmental conditions such as soil moisture and ambient temperature since these are not easily measurable qualities [16].

The system aims to aid the customer with various problems faced with gardening, such as;

1. Inconsistent Soil Moisture: Many plant owners struggle with maintaining the optimal moisture level for each plant and determining when each plant should be watered. Incorrect watering can lead to issues such as root rot, wilting, or drought stress, ultimately affecting plant health and growth [17].
2. Weather Variability: Weather is a vital environmental factor that influences plant metabolism and growth cycles. Indoor plants are particularly susceptible to indoor air temperature fluctuations, which can change the temperature of the soil and may lead to stunted growth, or even death of the plant [18].
3. Resource Management: Effective gardening requires significant time and effort, especially in monitoring and adjusting environmental conditions manually. Gardeners with limited time may find it challenging to consistently check and adjust environmental parameters, leading to neglected plants [19].

The system aims to address these challenges by providing real-time data on soil moisture and temperature, enabling gardeners to make informed decisions that ensure their plants thrive in optimal conditions. This solution is designed to simplify plant care, improve plant survival rates, and enhance the overall gardening experience by reducing the guesswork and manual effort involved in plant maintenance.

Stakeholders:

1. Home Plant Owners: Primary users who will directly interact with the system to monitor and maintain their plant health. They are interested in the system's reliability, ease of use, and accuracy.
2. Plant Nurseries and Retailers: Could use the system to maintain optimal conditions for plants, thus reducing losses and improving sales.
3. Commercial Farmers: Could use the system on a larger scale to monitor multiple fields or greenhouses. They require robust, scalable solutions that can integrate with other farming technologies.
4. Botanical Researchers: Interested in detailed data collection for research purposes. They might focus on the system's ability to provide accurate and consistent environmental readings.
5. Graduate TA: Evaluates the project's technical and functional adherence to academic standards

Initial Requirements

Functional requirements

1. **Wireless Communication Distance**
    - Requirement: Maintain mutual connection between sensor (microcontroller 1) and user interface (microcontroller 2) over a range of 15 meters at baud rate 38400
    - Permitted Range: 5m ≤ distance ≤ 25m
    - Measurement: Test signal transmission success rates at different distances
    - Reference: [1] HC-05 Bluetooth modules support ranges of up to 30m
      [2] In Ontario, the median above-grade living area of a single-detached house is 1,520 square feet. Square dimensions of 11.9m*11.9m, with a diagonal distance of 16.8m. To adjust to rectangular floor plans, the maximum transmission range is set to 25m.
2. **Temperature Measurement Accuracy**
    - Requirement: Measure the average temperature of the soil with an accuracy of ±1˚C
    - Permitted Range: 10˚C ≤ Temperature reading ≤ 50˚C
    - Measurement: Compare the temperature of a mercury thermometer with temperature reading of measurement device
    - Reference: [4] Most houseplants grow best in a soil temperature between 15-24°C
3. **Moisture Measurement Accuracy**
    - Requirement: the microcontroller must measure humidity of soil within 5%VWC (Volumetric Water Content)
    - Permitted Range: 21% ≤ water moisture ≤ 80%
    - Measurement: Measurement: calibration using an object of known humidity.
    - Reference: [6] Most houseplants grow optimally with water moisture of 21% to 80%

Technical requirements

1. **Thermocouple Range & Error Range**
    - Requirement: accurately measure temperature between 10˚C and 50˚C with accuracy of ±1˚C
    - Reference: [3] Standard thermocouples get within approximately 1% of the actual temperature at the measuring junction, which is about 0.5˚C at temperature reading of 50˚C
2. **Soil Moisture Sensor Range & Error Range**
    - Requirement: the microcontroller must measure humidity of soil within 5%VWC
    - Measurement: [measure the RH (relative humidity) of dry air and water to find the readings of 0%RH and 100%RH, and map other RH in between the readings.
    - Reference: [5] operating range of SKU:SEN0193 is between 10˚C and 60˚C, can read exact RH values

3. **Wireless Data Packet Size**
    - Requirement: Packet Size should not exceed 64 bytes, transmission success rate above 98%
    - Permitted Range: packet size ≤ 64 bytes
    - Measurement: inspect and calculate packet size in firmware code
    - Reference: [7] hc-05 Bluetooth maximum packet size range from 1kb to 3kb depending on the distance
4. **Screen Size**
    - Requirement: LCD screens must display 32 characters with character font size of at least 24 (~8.5mm)
    - Permitted Range: character size ≥ 8.5mm
    - Reference: [8] The recommended font size for comfortable reading from 10 feet away is 72, 1m is 3.3 feet and thus the recommended font size is 24.

Safety requirements

1. **Environmental Resistance:**
    - Requirement: Microcontroller must be encased in a water-resistant casing to protect against accidental water spills and high moisture levels (IPX4 rating).
    - Permitted Range: Must meet IPX4 water resistance standards.
    - Measurement: Test by exposing item to an oscillating spray for a minimum of 10 minutes, as per IPX4 guidelines
    - Reference: [9] IEC 60529:2013 Defines ingress protection ratings for Enclosures.
2. **Energy Consumption:**
    - Requirement: the system will not consume, transfer, or discharge more than 30W of energy
    - Permitted Range: power ≤ 30W
    - Measurement: use a voltmeter to measure voltage and current to calculate power consumption
    - References: Project rubric
3. **Energy Storage:**
    - Requirement: The system will not store more than 500 mW of energy at any point in time
    - Permitted Range: power stored ≤ 500 mW
    - Measurement: use equations for any necessary energy storage components (inductor, capacitor, etc) to calculate energy stored
    - References: Project rubric

Principles

To test our energy consumption, power will be calculated using the equation:

- [10]: P=IV

where,
P = power
V = the difference in voltage between the cathode and anode of the power supply
I = current

In addition, we will be converting the readings from RH to VWC, which includes a multi-step equation: [11]

1. Calculating soil water potential: $\psi = \frac{RT}{V_m}\ln(\mathrm{RH})$
   - ψ = soil water potential
   - R = universal gas constant
   - V_m = molar volume of water
   - RH = relative humidity
2. Van Genuchten's (1980) model to calculate VWC $\theta = \theta_r + \frac{\theta_s - \theta_r}{[1 + (\alpha|\psi|)^n]^{1-1/n}}$
   - θ = VWC
   - θ_s = saturated water content for given soil type
   - θ_r = residual water content for given soil type
   - α: soil-specific constant for how easily soil pores begin to drain
   - n: soil specific constant
   - ψ = soil water potential
   - Refer to [12] for soil-specific constants

IEEE 802.15.1 (Bluetooth Standard): [13] Specifies the requirements for Bluetooth communication, including transmission distance, baud rates, and data packet management. Relevantly, it outlines the core specification of Bluetooth 2.0, which we will refer to in our implementation of Bluetooth communication. We will also reference the text about Bluetooth Profiles, which define how applications use Bluetooth communication, including Serial Port Profile (SPP)

ISO 9241-303 (Ergonomics of Human-System Interaction): [14] Provides guidelines for screen readability, including font size and character spacing, aligning with our LCD screen requirements for comfortable reading.

IEEE 1566 (Standards for Power Electronics): Will be referenced to outline guidelines and measurement techniques for low-power electronic devices, relevant to our power consumption requirement of < 30W.

Citations:

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