PROJECT MILESTONE 2

MACHINE LEARNING-POWERED SMART AGRICULTURE SYSTEM

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MOTIVATION: Accompanied by climate change and expanding global food demand in the face of food insecurity due to resource scarcity, the need for smarter and more efficient agricultural practices is increasingly relevant. Conventional agricultural practices often lead to inefficient irrigation and excessive water consumption, and there are opportunities to improve crop yield and farm costs. Utilizing Machine Learning and IoT devices to collect data on farm operations opens the door to more information and data-driven practices, optimizing water and resource utilization, and improving the health of crops. The Machine Learning-Powered Smart Agriculture System is designed to address these needs through real-time sensing data, predictive analysis, and a degree of automation. This project builds on sustainability and food security efforts but is also consistent with the future of precision agriculture that seeks to make farming more efficient, cost effective, and good for our environment.

SYSTEM ARCHITECTURE DIAGRAM

The system architecture contains multiple hardware elements that are connected to providing automated irrigation and monitoring based on AI and IoT technologies. In addition to this architecture, it is designed to ensure poor data collection does not occur, allow for enough data processing, and enact actions while doing so. The important components include the following:

Core Elements

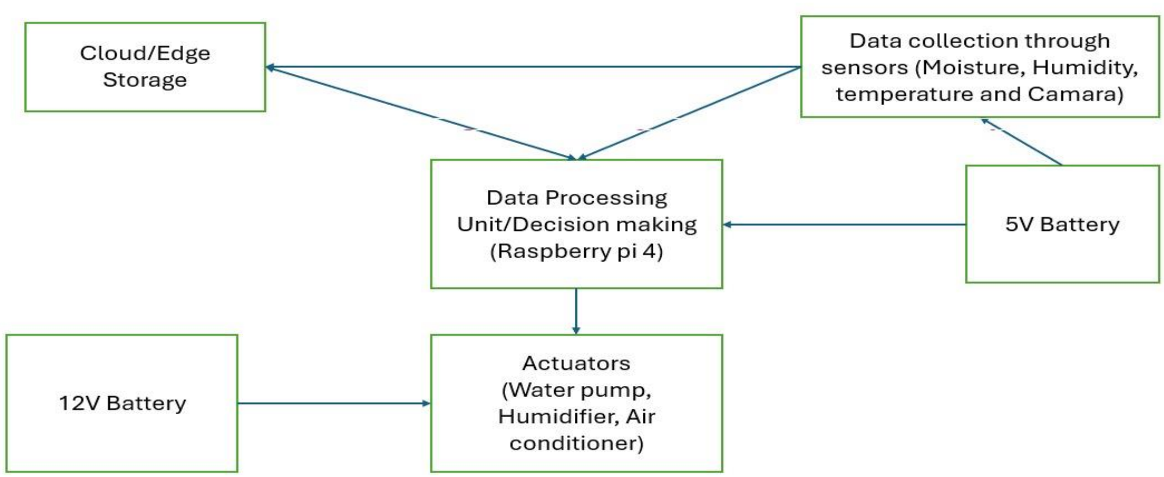
- **Sensors:** Soil moisture sensors, temperature, and humidity sensors gather real-time environmental information required for making decisions about irrigation and climate.
- **Microcontroller:** A Raspberry Pi 4 processes data from the sensors, runs ML scripts, and connects to actuators.
- **Communication Modules:** Wi-Fi and MQTT protocol connector enable communication between the system and cloud storage, and the user interface to the system.
- **Actuator:** The water pump and humidifier automatically regulate irrigation and environmental conditions based on sensor information and ML predictions.

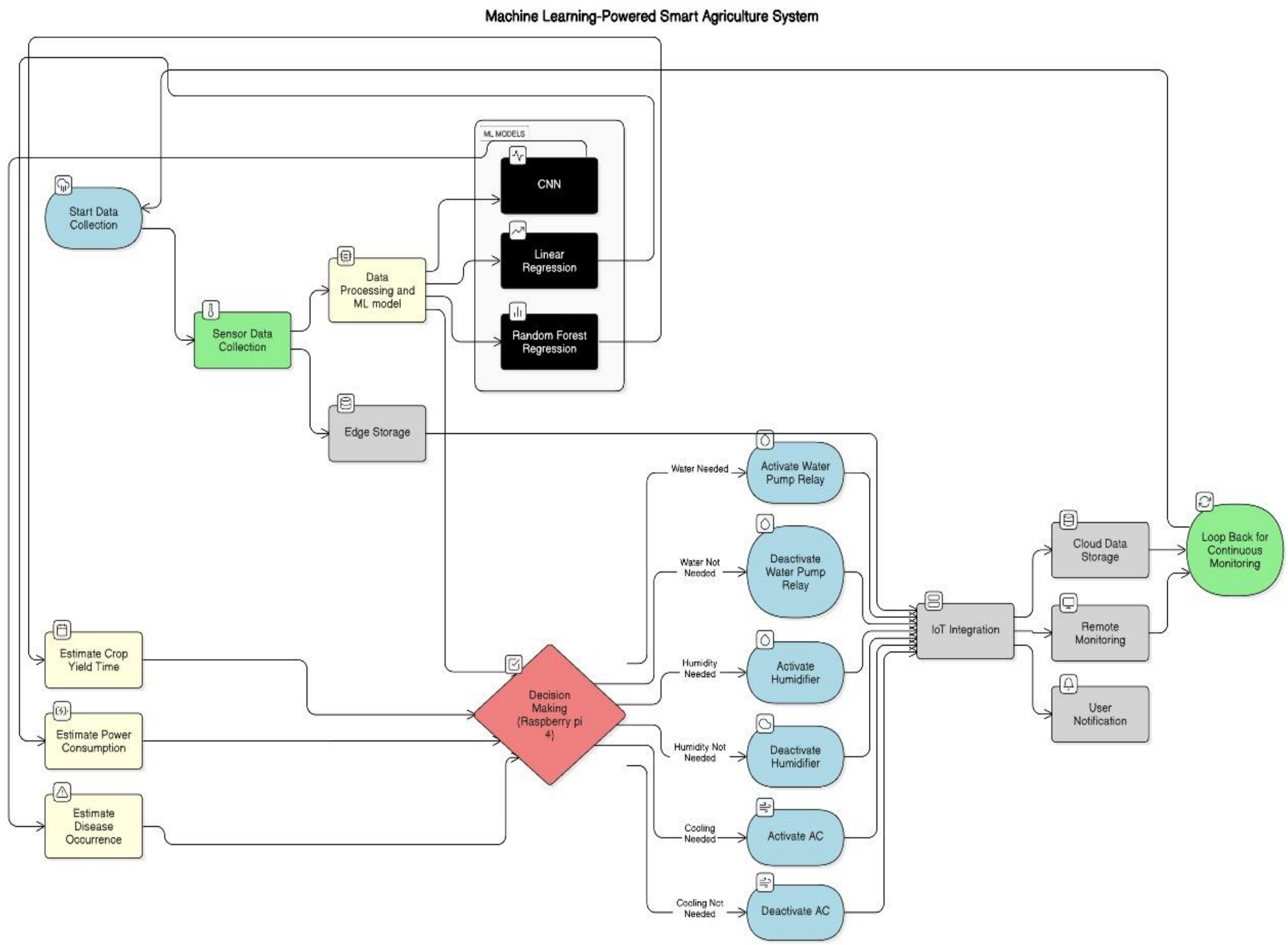
- **Power Supply**: A 5V USB adapter powers the Raspberry Pi and sensors, and a 12V powers the water pump.
- **Cloud/Server:** Data can be logged into cloud storage, which allows for remote monitoring and analysis.
- **LCD/OLED Display:** Allows users to view sensor readings and system status in real-time for ease of use.

Data Flow and System Operations

- **Data Collection:** In the agricultural field, sensors are used to record soil moisture, temperature, humidity level.
- **Processing & Decision Making:** Sensor data is collected by Raspberry Pi 4, which processes the data through ML models to determine the need for irrigation. The system also uses historical trends as well as real-time data to make predictions for better use of water and resources.
- **Communication:** Data is transferred for remote access through cloud storage. The system issues alerts and updates to users through an IoT dashboard and/or a mobile app.
- **Actuation:** When soil moisture is below the specified threshold, the Raspberry Pi activates the water pump to irrigate the field. Likewise, when the environmental factors call for adjustment, the humidifier is activated.
- **Feedback Loop:** Sensor data is updated continuously to refine ML models and improve accuracy of the system.

The block diagram below is the simple representation of Machine Learning-Powered Agriculture System





The above block diagram is the data flow of the Machine Learning-Powered Agriculture System

HARDWARE COMPONENT SELECTION

Required Hardware Components

Raspberry Pi 4

- **Specifications:** Quad-core CPU, Wi-Fi, Bluetooth, GPIO enablement
- **Justification:** Provides enough processing power to execute machine learning algorithms with the capacity to connect to IoT.
- **Alternative:** Arduino with external Wi-Fi module (Not selected as it has less processing capability for machine learning purposes).
- **URL:** https://www.amazon.com/Raspberry-Model-2019-Quad-Bluetooth/dp/B07TC2BK1X

Soil Moisture Sensor

- **Specifications:** Operating voltage 3.3V–5V, Analog output
- **Justification:** Provides soil moisture data that can be evaluated in real-time to trigger the irrigation system.
- **Alternative:** Capacitive moisture sensor (Was not chosen as it is more expensive to produce but has less power consumption)
- **URL:** https://www.amazon.com/SparkFun-Soil-Moisture-Sensor/dp/B077GGPFD3?source=ps-sl-shoppingads-lpcontext&ref_=fplfs&psc=1&smid=AAEX2EKCSXB7D&gQT=1

Temperature and Humidity Sensor (DHT22)

- **Specifications:** Operating voltage 3.3V–6V; Humidity accuracy ±2–5%.
- **Justification:** Important to keep track of the environmental conditions.
- **Alternative:** BME280 (Was not chosen because they were too expensive)
- **URL:** https://www.adafruit.com/product/385

Water Pump

- **Specifications:** 12V, 5W
- **Justification:** Used to automate the irrigation system based on ML predictions.
- **Alternative:** AC powered pump (Was not chosen because of their higher electrical consumption)
- **URL:** https://www.amazon.com/AITIAO-Submersible-Fountain-Aquarium-Garden/dp/B0B6HN5K4W/ref=asc_df_B0B6HN5K4W?mcid=d5f198881dda3ecfa672589b2d1b5387&tag=hyprod-20&linkCode=df0&hvadid=693348290062&hvpos=&hvnetw=g&hvrand=14279028114779233425&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9027286&hvtargid=pla-1730552143802&psc=1

LCD/OLED Display

- **Specifications:** 128x64 OLED; I2C communication
- **Justification:** Used to provide real time data for sensor data and system status.
- **Alternative:** 16x2 LCD (Not preferred due to a lower resolution and not having graphical capabilities).
- **URL:** https://www.adafruit.com/product/326

POWER CONSUMPTION ANALYSIS

Estimated Power Usage

- **Raspberry Pi 4:** Roughly 3W
- **Combined Sensors:** Around 1.5W
- **Water Pump:** Approx. 5W (will not run unless called for)
- **Humidifier & Air Conditioning:** Approximately 2.5W
- **LCD or OLED Display**: About 0.1W

Power Source Justifications

- **5V USB Power Adapter:** Supplies stable energy for raspberry pi and sensors
- **12V Power Supply:** Designed to deliver proper energy to water pumps.
- **Alternative Power Supply:** Consider a system using solar power with a battery backup for sustainability; However, the efficiency vs cost needs more evaluation.

Power Management Strategies

- **Deep Sleep Mode for sensors:** Sensors that are not essential can be put to deep sleep until that are called upon minimizing energy draw.
- **Duty Cycles Optimization:** Actuators and Sensors need to operate for small time intervals rather than continuous operation energy use.
- **Selected Low Power Components:** By using components such as ESP8266 that have sleep mode settings we can reduce the use of energy.
- **Load Balancing in Power Supply:** Ensure that energy is distributed evenly between power sources to avoid draining any single source. Energy efficiency and duration would be improved.

COMMUNICATION AND DATA FLOW

Interaction among Components

- **Wi-Fi (ESP8266):** Allows for the interaction between Raspberry Pi, cloud storage, and user interface.
- **MQTT Protocol:** Allows for efficient and lightweight data transfer between the microcontroller and the cloud.
- **I2C & GPIO:** Used to interface sensors and actuators with Raspberry Pi.

Data Processing and Transmission

- **Gathering Sensor Data:** Sensors continuously gather soil and environmental data.

- **Data Processing:** The Raspberry Pi interprets raw sensor data with ML algorithms, determining irrigation needs.
- **Data Sending:** The processed data is sent to a cloud database through Wi-Fi. Alerts and updates are relayed to users through an IoT dashboard or mobile app.
- **Actuation:** If needed, based on ML predictions, the Raspberry Pi will activate the water pump or humidifier.
- **Data Logging & Retrieval:** Sensor readings and ML predictions are stored in the cloud for historical analysis. Users can access real-time and past data remotely for informed decisions.

SYSTEM INTEGRATION CHALLENGES AND SOLUTIONS

Hardware Compatibility

- **Issue:** Achieving a proper connection to the sensors, Raspberry Pi, and actuators.
- **Solution:** Using standard I2C/GPIO interfaces is a common practice.

Power Management

- **Challenge:** The significant battery drain associated with continuous operation.
- **Solution:** Using deep sleep mode with sensors, and duty cycles.

IoT Connectivity

- **Challenge:** Data transfer efficiency and transmission latency.
- **Solution:** Using a specific packet messaging protocol called MQTT to communicate and decrease network bandwidth usage.

This system design helps to create a smart agriculture system using Machine Learning and IoT technologies with automation, along with a robust power management and portability system.