Boston University
Electrical & Computer Engineering
EC 464 Senior Design Project

Final Product Testing Plan

Simple Sprouts

by
Team 26

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Required Materials

Hardware:

- Raspberry Pi 5
- 24V DC Power Supply
- 24V to 12V DC-DC Converter
- 24V to 5V DC-DC Converter
- 12V to 5V DC-USB-C Output Converter
- Raspberry NoIR Camera Module (2)
- 12V Water Cooled Water Pump Air Diaphragm Pump
- 12V Peltier Heating Module with Heat Sink and Fan
- 12V Solenoid Valves (2)
- Grow Light LED Strips (2)
- Soil Moisture Sensors (2)
- Temperature Sensor
- Humidity Sensor
- Air Quality Sensor
- Custom Fully Assembled PCB

Software:

- Python Scripts (Raspberry Pi GPIO control w/ scheduling logic, sensor handling)
- Capturing Photos & Object Recognition (OpenCV, TensorFlow for plant analysis)
- React Native Expo (Mobile/Web UI for monitoring and control)
- Node.js Web Server (Data visualization and API communication)
- Adafruit Sensor Libraries (for data collection from environmental sensors)
- Firebase (Cloud-based data storage and real-time updates for system communication)

Modes of Operation:

1. **Manual Mode:** User manually controls watering and lighting via the web app.
2. **Schedule Mode:** User sets their own or one of the predefined schedules for watering and lighting cycles.
3. **Adaptive Mode:** System responds dynamically based on sensor input and camera feedback.

Set Up

The system consists of the following components:

- **Raspberry Pi 5:** Manages all sensor readings (soil moisture, temperature, humidity, air quality, water lever), controls the solenoid valves, water pump, and grow lights via GPIO-PCB control (using MOSFETs for on/off function), and processes infrared images for plant health monitoring. Handles requests with vision model for plant health
- **Power Distribution:** Uses a 24V DC power supply with three DC-DC converters (12V for the water pump, solenoids, and heater, 5V for the grow lights, and 5V USB-C for the Raspberry Pi).
- **Web App:** Displays real-time sensor data, images captured by the camera, and AI-based plant health assessments. Allows users to control and monitor the system remotely.
- **Peltier Module:** Maintains internal temperature within the optimal range for plant growth.
- **Sweet Basil & Hot Banana Peppers:** Test crops; the peppers were selected for their bright color to enhance camera-based plant health detection. Basil and other leafy greens like lettuce and spinach account for over 57% of crops grown in vertical farming systems.

All systems are now built on the custom PCB, replacing the individual breadboard circuits.

Pre-testing Setup Procedure

1. Connect all sensors (soil moisture, temperature, humidity, air quality, water level) to the Raspberry Pi and verify communication with RPI and Firebase
2. Ensure the Raspberry Pi is connected to the NoIR Cameras and can capture infrared images using Python. Ensure the Pi can process images using OpenCV and NVDI
3. Verify optimal water levels in storage manually.
4. Set up the DC power supply to provide 12V power for the water circuit and 5V for the Raspberry Pi and grow lights.
5. Ensure proper control of the water pump, solenoid valves, LED strips, and heater through the MOSFETs.
6. Upload and run the control code on the Raspberry Pi for automation and monitoring. Ensure timing for schedules is accurate
7. Run a test script to ensure image capture and AI-based plant monitoring functions correctly.
8. <u>*Continuity Testing</u>
    a. Inspect PCB solder joints (MOSFETs, diodes) and water pump health (due to manufacturer's notice).

Workflow Testing

1. **Grow Light Activation**
    - Triggered via Raspberry Pi GPIO control through Schedule, Manual, or Adaptive mode.
2. **Watering System**
    - Soil moisture sensor triggers water pump via Raspberry Pi in adaptive mode. In scheduling mode, the water pump and valves are triggered using timing schedules.
    - Water pump and respective level is manually activated via Pi logic through the app.
    - Water flows from the water pump to the Y-Connector and then through its respective solenoid valve.
        1. Confirmed visually and through moisture sensor readings.
3. **Camera & AI Processing**
    - Camera captures plant images with a NoIR and processes it to create an NDVI image to make assessing plant health easier
    - Web app displays sensor data, IR plant images, and AI-based assessments.
4. **Sensor Integration**
    - All environmental sensors upload real-time data to Firebase.
    - Ultrasonic sensor detects and reports low water levels.
    - Sensor script stores historical sensor data every twelve hours
5. **Heater Module Test**
    - Activates automatically via Raspberry Pi Logic when enclosure temperature falls below 75℉ (± 5℉).
        1. *Note For purposes of manual testing, this threshold can be set to a lower value in the code.

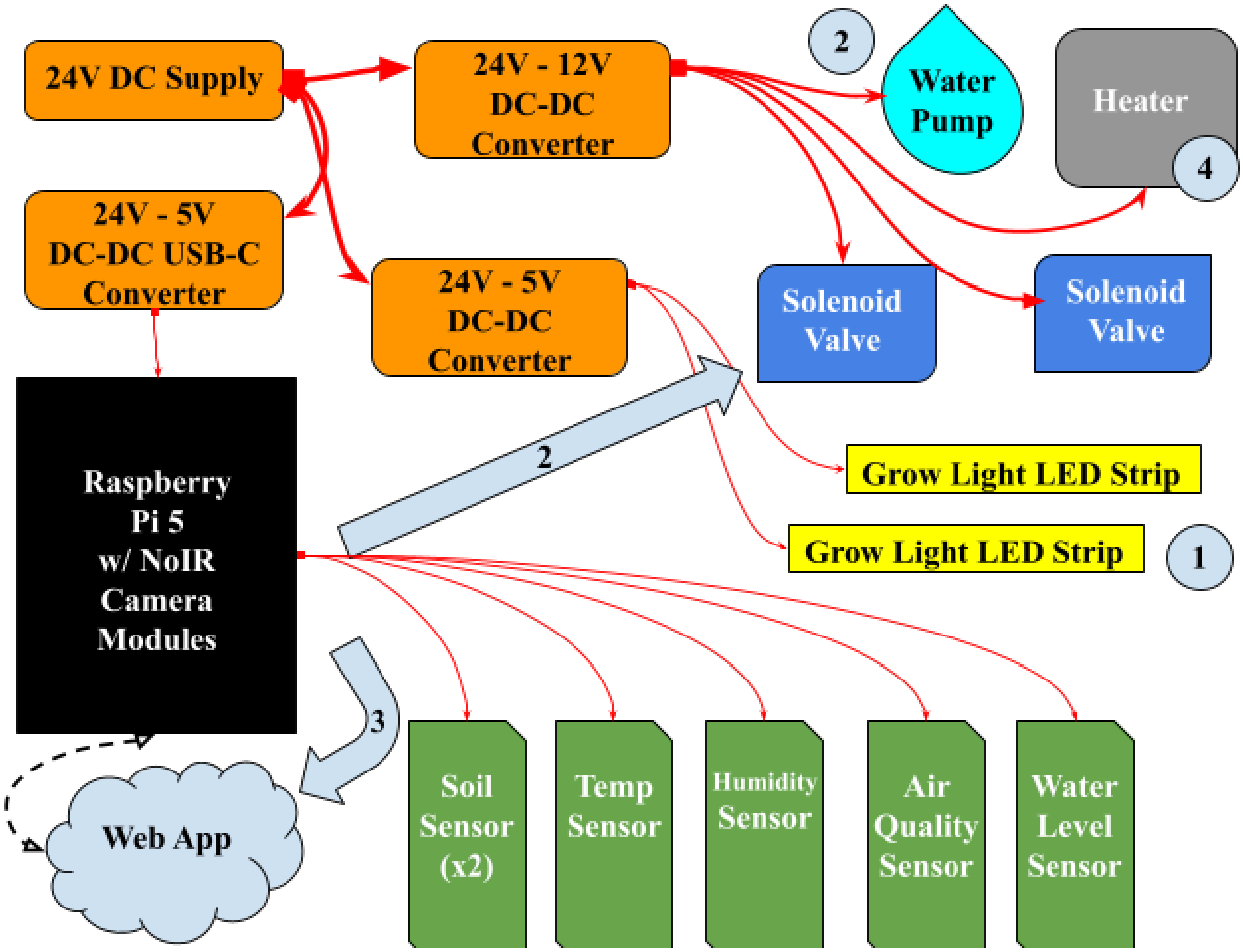

Figure 1: Illustration of Setup and Process Flow

Testing Procedure

Grow Light Test

- Confirm that the Raspberry Pi can toggle grow lights through both manual and scheduled modes via the web app.
- Ensure activation is time-aligned with defined schedule parameters.

Watering System & Soil Moisture Test

- Measure real-time soil moisture data from both sensors.
- Trigger watering cycle when soil moisture falls below a set threshold.
- Confirm pump activation and water flow through solenoid valves and Y-connector.
- Validate that the pump stops automatically once the desired moisture level is reached.
- Manually toggle watering ON/OFF from the app and verify the response.

Camera & AI Image Processing Test

- Capture images of Sweet Basil and Hot Banana Pepper plants using NoIR cameras.
- Uses MoonDream cloud API to evaluate plant health and get advice based on the images taken
- Confirm that captured images are correctly processed and health classifications are sent to the web dashboard through firebase.

Environmental Sensor Integration Test

- Collect real-time data from all sensors:
    - Soil Moisture
    - Temperature
    - Humidity
    - Air Quality
    - Ultrasonic Distance Sensor (for water reservoir level)
- Ensure Raspberry Pi receives accurate readings and pushes updates to Firebase.
- Confirm data is correctly parsed and displayed on the web app interface with minimal lag or data loss.

Heating & Cooling System Test

- Test GPIO control of the heater module.
- Monitor temperature changes through the environment sensor before and after activation.
- Ensure thermal regulation maintains the desired enclosure range.

Measurable Criteria

Test Case	Expected Outcome	Pass/Fail
Grow Light Control A. *Scheduled mode* *B. Manual mode* *C. Adaptive mode*	Lights turn on/off as scheduled or in manual mode. Lights follow schedule set by model in adaptive mode	
Water Pump Activation *A. Scheduled mode* *B. Manual mode* *C. Adaptive mode*	Water pump & its respective solenoid valve turns on/off as scheduled or in manual mode Water pump & its respective solenoid valve turns on/off when the soil moisture sensor detects dry soil	
Image Capture	Successful infrared image	

	capture	
AI Plant Assessment	Accurate AI evaluation of plant health	
Sensor Data Display	Real-time data from temp/humidity/moisture/air/ultrasonic sensors is uploaded to web app and Firebase	
Heating Functionality	Heating on/off toggles via Pi, confirmed by temperature changes	

Additional Observations

- LED strips powered via PCB are brighter and more stable than in the breadboard prototype.
- System wiring is fully enclosed and neatly mounted.
- It is much more convenient with the PCB due to its terminal blocks for the systems' wiring and the 4-pin connectors for the sensors' wiring.
- Final hardware is now installed into a fully enclosed, multi-layer wooden frame with acrylic facing, allowing full view of the crops front and back.
- Ultrasonic sensor provides additional robustness by alerting users when the water tank needs refilling.
- Replacing SRDs improved overall power reliability and reduced noise during operation.

Future Steps (Pre-ECE Day)

- Make a permanent mounted enclosure for the water level sensor on the water tank.
- Re-apply paint to improve visual appeal.
- Laser engrave the team logo and name onto the side of the frame.
- Clean up wiring.
- Keep the system running to take care of our crops for ECE Day.

Conclusion

The Simple Sprouts project represents a fully integrated and functional automated plant care system, combining sensor feedback, intelligent control, and user interaction through a custom web interface. With the successful completion of the PCB build, full system soldering, and enclosure construction, the prototype now supports stable and efficient operation. New additions like the ultrasonic distance sensor and Peltier heating module enhance environmental control, while the grow lights, soil moisture sensors, and solenoid-pump irrigation system operate reliably through both scheduled and manual modes.

The inclusion of Sweet Basil and Hot Banana Peppers not only serves functional irrigation testing but also strengthens our AI model’s performance in real-time plant health monitoring through IR imaging. The bright coloration of the peppers improves contrast and detection accuracy for camera-based analysis. Cloud synchronization via Firebase enables seamless data flow between the Raspberry Pi and the web dashboard, maintaining live system transparency and control.

By completing the final hardware implementation, integrating all power, irrigation, and sensor systems into a unified architecture, Simple Sprouts is now positioned as a robust, scalable smart agriculture solution. Future directions will explore enhancing adaptive logic, expanding AI-based care recommendations, and refining mechanical features for long-term deployment.