PlantPulse

A Plant Health Monitoring System

Authors:

Kevin Shook	Joshua Barshay	Fabrizio Martins
Computer Engineering	*Electrical Engineering*	*Computer Engineering*

Review Committee:

Dr. Zakhia Abichar	ECE	Associate Lecturer
Dr. Mark Maddox	ECE	Adjunct Professor
Dr. Piotr Kulik	ECE	Assistant Professor

1 - PROJECT DESCRIPTION

1.1 PROJECT BACKGROUND AND MOTIVATION

Home gardening is increasing in popularity among many Americans, whether it is for at home sustainability or simply a hobby. With this type of endeavor, however, comes the challenge of monitoring the wellbeing of the plants which are being cared for. Without various tools, it is nearly impossible to keep track of all the necessary measurements required to successfully care for and grow a home garden. The goal of our project, PlantPulse, is to alleviate the difficulty in managing a home garden by providing an all-in-one solution to monitoring plant health allowing for an easier time gardening.

One of the major goals of the Senior Design project is to demonstrate all our prior knowledge and gain a more real-world experience by collaborating with a group to solve or alleviate a real-world problem. When discussing ideas for the project initially, the group was trying to decide on an impactful problem to work towards which would leverage the skills of everyone in the group.

We came across the idea of plant health monitoring as we had known many people who tried to dip their toes into home gardening as an interest but gave up due to little success without a proper monitoring system. Even with a monitoring system, with no real way of determining the condition of the plant's health itself, the result was the same. This gave way to the idea of a device that would monitor the conditions surrounding the plants themselves and transmit this information to the user along with a general measure of the plants overall health to ensure the user knows exactly how their plant is doing at any given time.

1.2 CURRENT TECHNOLOGY

When it comes to gardening, aside from external factors such as the weather and pests, there are several factors that contribute to the health of the plants. These include soil quality, sunlight, soil moisture, which many products in this market currently offer solutions for. The Normalized Difference Vegetation Index (NDVI) which is used to quantify the health and density of vegetation is also used currently to monitor plant health in many commercial settings to assist gardeners with maintaining optimal plant health. Both types of devices are quite prevalent with notable examples coming from companies such as Photon Systems Instruments and TheConnectedShop.

Our goal was to build upon this technology in a way that would make it convenient to utilize both technologies in tandem to provide an optimal plant health monitoring system. This provides general information such as moisture level and utilizes NDVI to provide an overall reading of the plants health which would allow the average consumer to easily determine how healthy their plants are and determine which measurements require attention and by how much. PlantPulse will include a temperature and humidity sensor, a moisture sensor, a UV index sensor, and a near infrared (NIR) camera that will allow the system to determine the NDVI. All these metrics will then be displayed to the user via either web app or mobile app on regular intervals.

1.3 OBJECTIVE AND GOALS

The main goal of the PlantPulse project is to create a plant monitoring device that incorporates basic measurement sensing with more advanced NDVI technology to provide a simple and effective way to determine plant health.

The subgoals and objectives required for this project can be seen below:

Goals:

- The user will be able to interact with the device easily and effectively.
- The device will provide the user with periodic sensor measurements.
- The device will provide the user with an overall view of their plants health.

Stretch Goals:

- The device will be able to interface with the user via web application and mobile application.
- The device will be able to provide the user with various advanced suggestions based on current plant health metrics.
- Identification system of various plants, insects, and diseases.

Objectives:

- Autonomous humidity sensing of the air around the plants and sending the data to a database for collection.
- Autonomous ground moisture sensing and sending the data to a database for collection
- Autonomous NDVI imaging of plants using a NIR camera to obtain readings at set times at least three times a day.
- Autonomous ambient temperature sensing and using the sensed temperature to control the camera and sending the data to a database for collection.

· Autonomous UV light sensing and sending the data to a database for collection.
· Resistance to inclement weather conditions while maintaining an acceptable level of functionality.
· Monitor power is run on solar power or a rechargeable back-up battery without deliberate effort from the end user.
· Transmit all received sensor data from the database to the end user.
· Relay the NDVI readings to the user in easy to understand fashion.

2 - SPECIFICATIONS

2.1 REQUIREMENTS & CONSTRAINTS

<u>Marketing Requirements:</u>

- Monitor should be relatively low cost.
- Monitor should be able to function outdoors.
- Monitor should be accurate and reliable.
- Monitor should provide valuable plant-health information.
- Monitor should be able to run autonomously off solar power.
- Monitor should be easy to use with most plants including those low to the ground or high up.

<u>Solar Constraints:</u>

- A minimum of 4.4 average hours of solar performance in months with shorter days can be expected.
- Actual solar uptime can dip below 4.4 hours.
- The back-up battery must be able to power the system for a reasonable amount of solar downtime when fully charged.

<u>Weather/Temperature Constraints:</u>

- The device must be able to tolerate reasonable typical outdoor temperatures both high and low.
- The device must be resistant to inclement weather conditions such as rain or snow.

<u>Cost Constraints:</u>

- Less than or equal to $100 is the target maximum cost of the final design.
- $300 maximum budget we can put towards prototyping.

<u>Time Constraints:</u>

- 32 weeks to take the project from idea to realized design.
- 10 minutes of actual demonstration time (NDVI reading must be completed in this time).
- Extra time scheduled to account for unforeseen errors or problems.

Performance Constraints:

- The readings of the final device must be accurate enough for the device to properly fill its role as a plant health monitor.
- The final device should improve on existing designs by providing a level of quality that is acceptable while reducing cost as much as possible.
- The performance of the finished device should be consistent for all other rated operation conditions based on other constraints.

2.2 SPECIFICATION TABLE

Table 2.1 Specifications

Overall Device	
Parameter	Specification
Housing Tilt Function	60 Degrees
Device Max Response Delay	~1 minute
Device Total Max Cost	$100
Operating Temperature	-20-65 °C
Power Supply	
Parameter	Specification
Solar Panel Peak Voltage	5 V
Solar Panel Peak Power	0.6 W
Battery Life	2 Days
Sensors and Camera	
Parameter	Specification
Light Sensor Accuracy	90%
UV Light Sensor Input Range	260-360 nm
Camera Required NIR Sensitivity	830-870 nm

Temperature Sensor Input Range	-45-125 °C
Humidity Sensor Accuracy	90%
Humidity Sensor Input Range	0-100% RH

2.3 STANDARDS

I2C:

The sensors and charge controller must be controllable by the MCU via I2C to ensure that low power and consistent communication is possible. The MCU must also be capable of supporting the standard to communicate with the peripherals.

Waterproofing:

The PCB, sensors, and camera will all be outside for extended periods of time, so the enclosure needs to have an ingress protection rating of at least IPX4 or greater. IPX4 is a rating that ensures the enclosed electronics are resistant to splashing water from a spray nozzle. Similarly, the solar panel needs to have a similar IP rating.

WiFi:

To transmit the data to the database the MCU selected must be capable of communicating with the database via a 2.4GHz WiFi connection.

DVP:

The camera selected requires a DVP output which the MCU needs to be able to accommodate so that it can obtain the images from the camera for validation and uploading.

2.4 HOUSE OF QUALITY

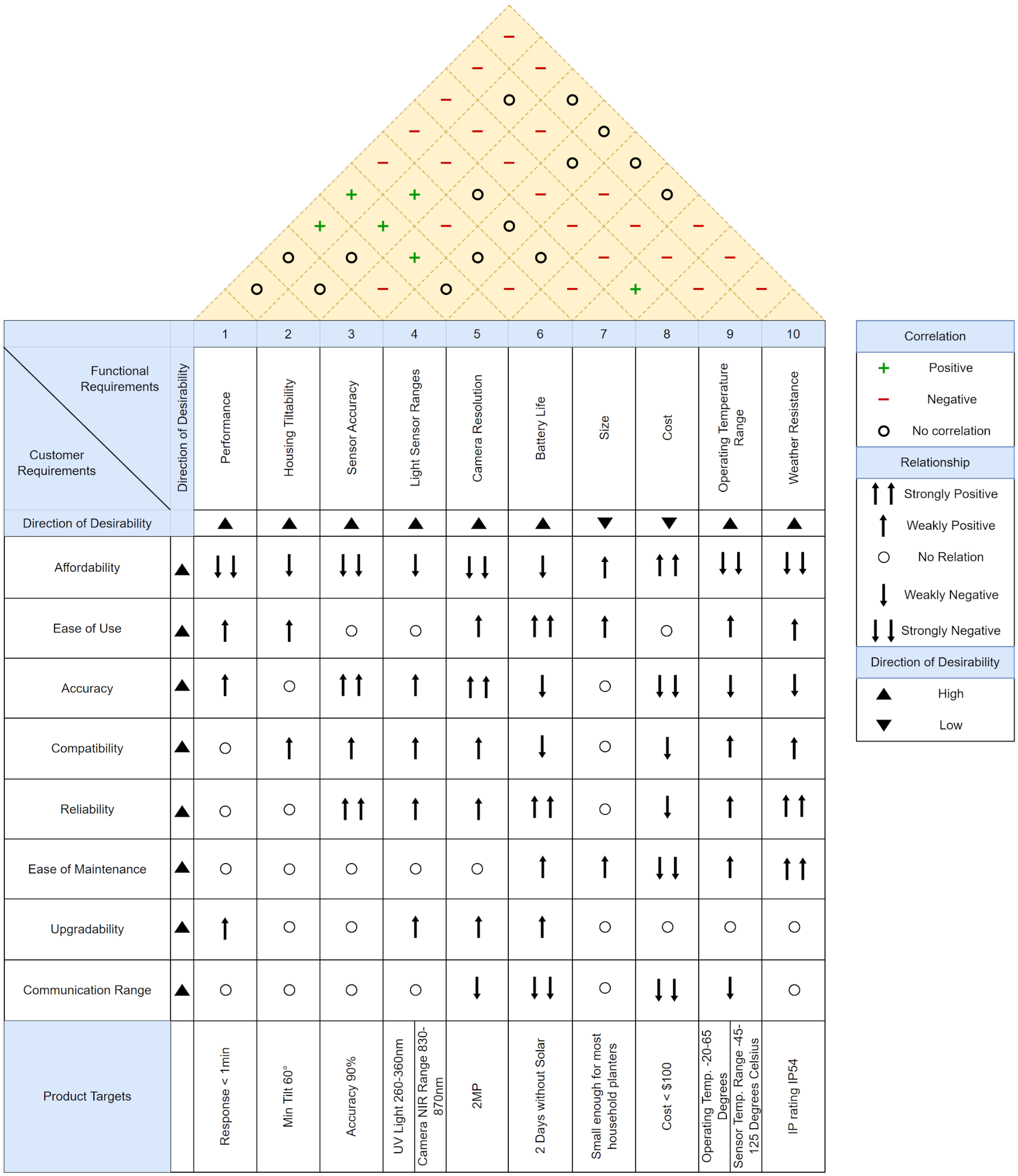

Figure 2.1 House of Quality

2.5 DEVICE ILLUSTRATION

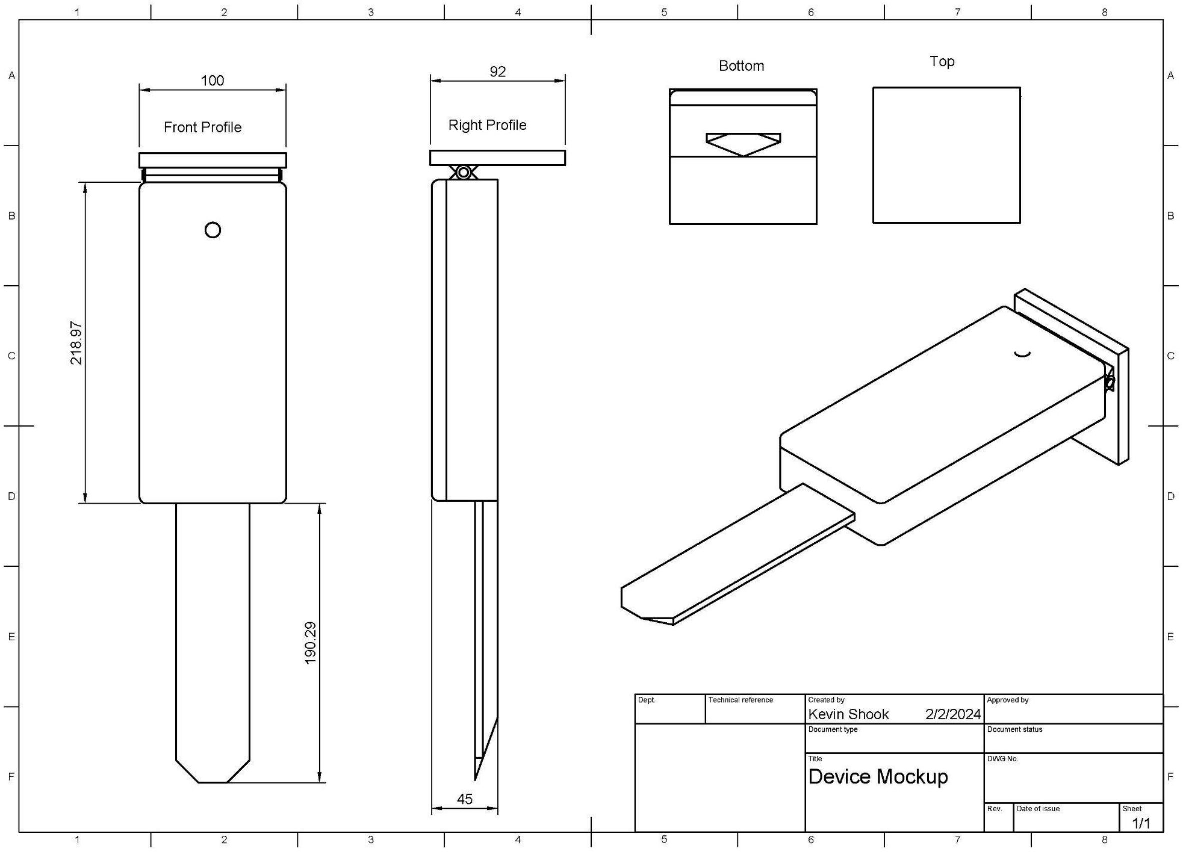

Figure 2.2 Device Mockup

2.6 HARDWARE BLOCK DIAGRAM

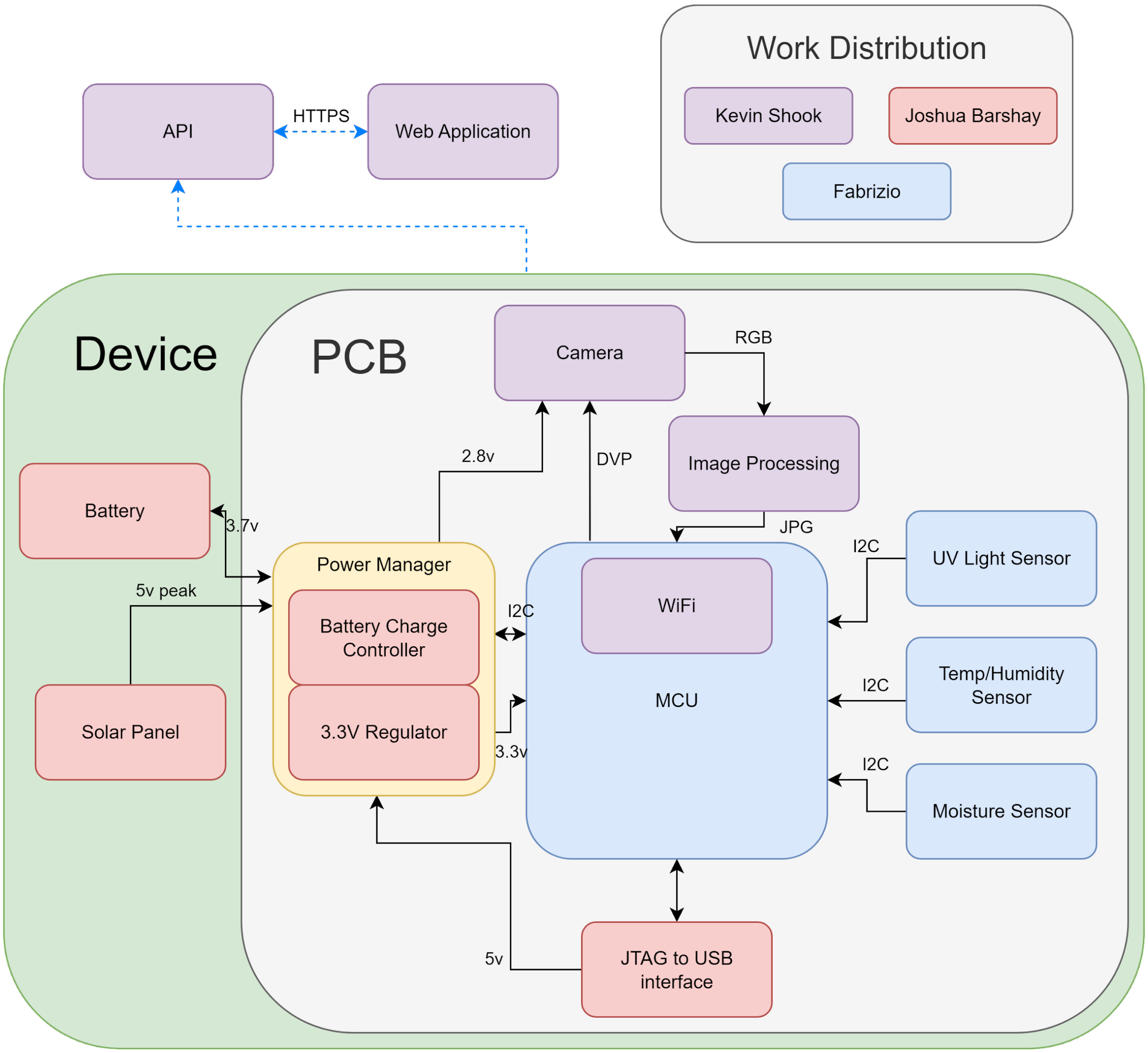

Figure 2.3 Device Hardware Diagram

2.7 SOFTWARE FLOW DIAGRAMS

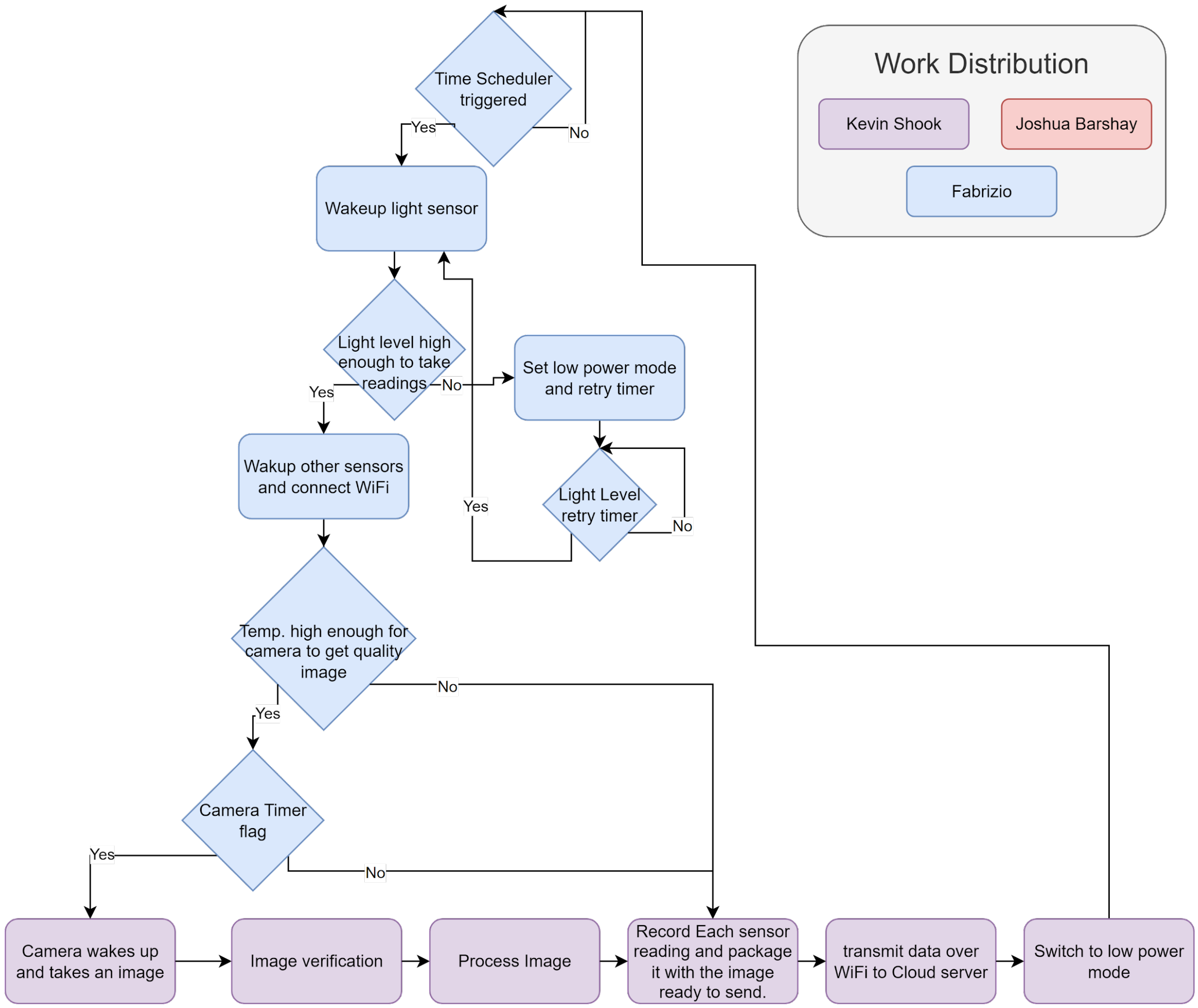

Figure 2.4 Device Software Diagram

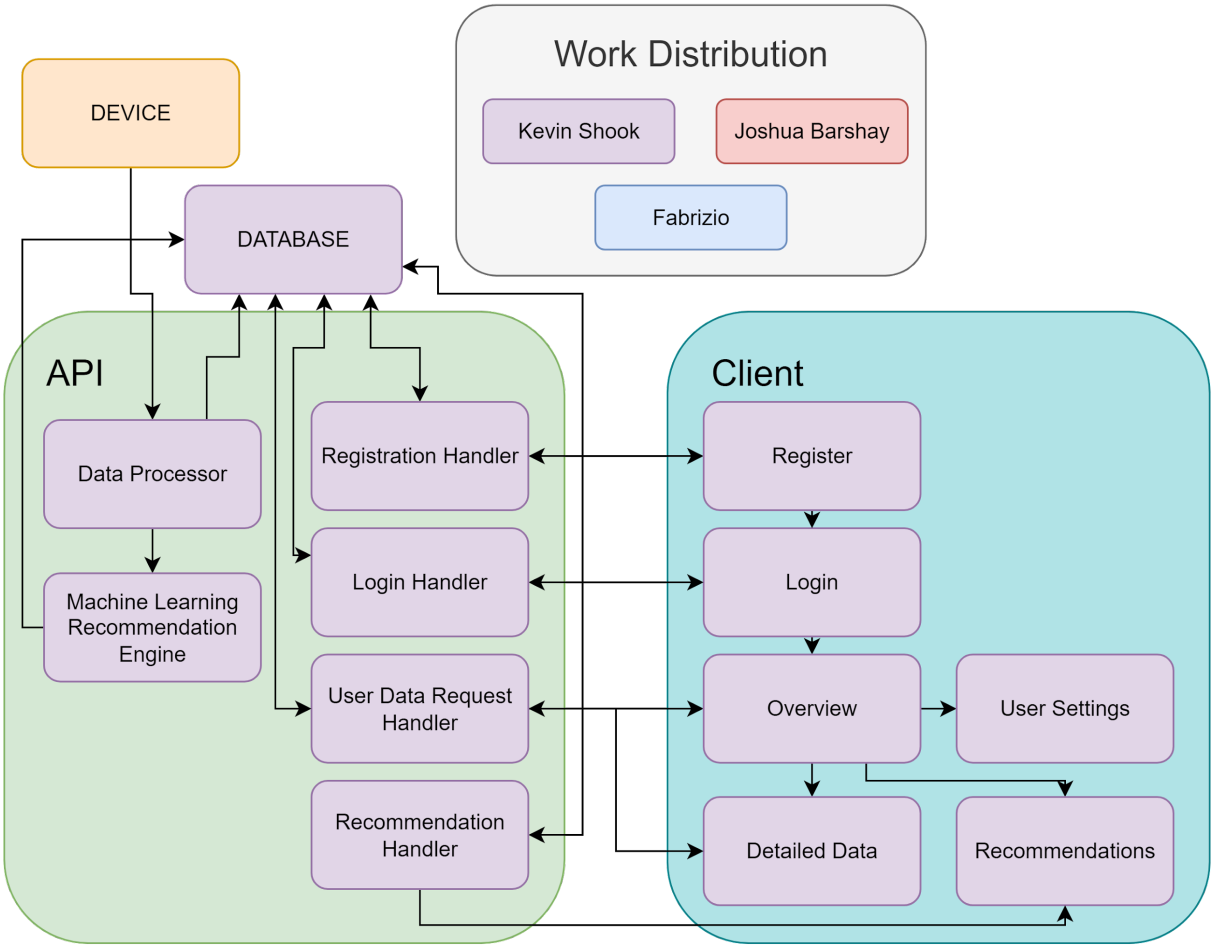

Figure 2.5 Web services and client application diagram

3 - FINANCIALS

3.1 BILL OF MATERIALS

We set a target for our device to cost less than one hundred dollars. The table below (Table 1) shows the total cost to build one device at our economy of scale. We were able to keep the cost down by using a very cheap yet powerful MCU with the ESP32 family of chips. We will build five devices for testing and demonstration purposes. The decision to create five devices comes from the five-board minimum from the PCB manufacturer. We also wanted plenty of devices to reduce the risk of hardware failure impacting our ability to demonstrate our device.

4 - MILESTONES

Table 4.1 Bill of Materials

Item	Model	Quantity	Price
MCU	ESP32-S3-WROOM-1-N16R8	1	$3.90
Camera	OV5640 noIR	1	$5.00
Temp/Humidity Sensor	SHT45	1	$7.18
Moisture Sensor	PIM520	1	$4.64
UV Light sensor	AS7331	1	$10.86
Power Regulator	TPS62933	1	$0.57
Solar charge controller	BQ25756E	1	$4.95
Solar Panel	Voltaic P123	1	$8.95
Battery	LIPO 552530 350mAh 3.7V	1	$5.95
PCB	PCBway	1	$5.00
3D Print material	ASA	180	$0.02
3D Print material	TPU	10	$0.02
		subtotal:	$61.18
	5 device	total:	$305.92

Table 4.2 Documentation Milestones

	Project Documentation Milestones			
Milestone	Details	Start Date	Planned Date	Due Date
Divide and Conquer Initial 10 Page Document	Tentative plan for the project including tentative BOM and specifications.	1/27/2024	2/2/2024	2/2/2024
Recruitment of Review Board	Recruited three professors from UCF faculty to serve as reviewers. Professors recruited: Mark Maddox, Zakhia Abichar, Piotr Kulik.	1/22/2024	1/31/2024	2/2/2024
60-Page Document	First two-thirds of the document.	1/27/2024	3/25/2024	3/29/2024
Final Document	Final SD 1 document.	1/27/2024	4/20/2024	4/23/2024

Table 4.3 Project Creation Milestones

	Project Creation Milestones			
Milestone	Details	Start Date	Planned Date	Due Date
Project Idea	Brainstorming and a meeting to go over various ideas for the project before deciding on one after deliberation.	1/11/2024	1/12/2024	2/2/2024
Component Selection	Selection of the essential components to begin system designs (e.g. MCU, camera, sensors, and charge controller).	1/15/2024	2/2/2024	2/7/2024
System Prototypes	Proof of concepts for the various hardware or software systems involved in the final project.	2/7/2024	4/16/2024	4/23/2024
Breadboard Prototyping	Finalization of design and testing on a breadboard.	4/23/2024	8/29/2024	9/2/2024
Software Prototyping	Implementation of software design and integration with the sensors done on the breadboard prototype before testing and finalizing.	8/19/2024	TBD SD2	TBD SD2
PCB Design/Manufacturing	Using the finalized design from prototyping to create the final PCB with Eagle and having the PCB manufactured.	9/2/2024	10/1/2024	TBD SD2
PCB Testing	Testing the PCB to ensure functionality and compatibility with software.	10/1/2024 (as soon as the PCB gets delivered)	TBD SD2	TBD SD2
Enclosure Fabrication	Creation of the housing for the PCB and sensors as well as the mount for the solar panel.	8/19/2024	TBD SD2	TBD SD2
Final Product Assembly and Testing	Final assembly of the product and testing in real-world settings to ensure functionality and ensure target accuracies are met.	TBD SD2	TBD SD2	TBD SD2

APPENDICES

APPENDIX A - references

[1] “BQ25756E,” BQ25756E data sheet, product information and support | TI.com, https://www.ti.com/product/BQ25756E (accessed Jan. 29, 2024).

[2] “TPS62933,” TPS62933 data sheet, product information and support | TI.com, https://www.ti.com/product/TPS62933 (accessed Jan. 22, 2024).

[3] C. Cox, “How to use solar panels to power the Arduino,” Circuit Basics, https://www.circuitbasics.com/how-to-use-solar-panels-to-power-the-arduino/ (accessed Jan. 30, 2024).

[4] “Relative humidity and temperature sensor - sensirion,” Sensirion, https://sensirion.com/media/documents/33FD6951/63E1087C/Datasheet_SHT4x_1.pdf (accessed Jan. 25, 2024).

[5] A. Industries, “5V 0.6W Mini Solar Panel - ETFE,” adafruit industries blog RSS, https://www.adafruit.com/product/5856 (accessed Jan. 22, 2024).

[6] “Is now - on semiconductor,” Onsemi, https://www.onsemi.com/pub/Collateral/DN06054.PDF (accessed Jan. 27, 2024).

[7] Ingress Protection (IP) ratings, https://www.iec.ch/ip-ratings (accessed Jan. 30, 2024).