Senior Design 1: Divide and Conquer

Tank Pack - A Fish Tank Helper

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1.0 Project Motivation & Background

For our senior design project, the motivation behind creating a smart aquarium that automates the care of fish stems from the desire to simplify and enhance the experience of being a pet fish owner. Many fish enthusiasts and pet owners often struggle to maintain a consistent and healthy environment for their aquatic pets due to busy schedules, forgetfulness, or the need to travel. The last concern is a significant contribution to our motivation behind the project, as it's not always easy for a fish owner to find someone who can take care of their fish pets. Moving a fish tank somewhere else while you are out of the country or far away from home is probably not a feasible idea, and finding someone trustworthy who can come into your house every day to take care of your fish may not always be possible.

By developing and integrating innovative technology into a fish tank, owners can ensure their fish receive optimal care without constant physical intervention. This innovation aims to monitor water quality, temperature, and oxygen level and allow automatic feeding schedules and remote checks through a live stream. Consequently, this can lead to healthier, longer-living fish and a more enjoyable, stress-free experience for the owners by reducing the risk of common issues such as forgetting to feed the fish or letting poor water conditions go unnoticed for long periods of time.

The importance of a smart aquarium goes beyond convenience as it addresses the well-being of the fish regardless of experience level. For a beginner, taking care of fish may be a steep learning curve, requiring constant aquarium monitoring to ensure its well-being. A smart aquarium provides a safety net by offering real-time feedback and automated adjustments, making fishkeeping more accessible to novices. On the other hand, seasoned aquarists won't likely face this issue. However, this technology is still beneficial in their case since it offers an advanced monitoring solution, allowing them to focus on the more enjoyable aspects of their hobby. Ultimately, this technology not only enhances the quality of life for the fish but also promotes better care practices across the board.

As engineering students, creating a smart aquarium offers us a unique opportunity to apply the knowledge and skills acquired throughout our studies to solve a real-world problem since the level of freedom this project provides is one, we won't likely be able to experience under the rigorous schedule of an engineering company. Additionally, it tackles our challenges of owning and maintaining a fish tank while balancing personal and academic responsibilities, such as the need to travel out of the country or spend extended hours on campus. This project not only serves as a practical solution to our personal challenges or different experience level owners but also highlights our abilities by working as a team and applying project management skills and hardware and software development skills, preparing us for future endeavors in the engineering industry.

1.1 Pre-existent Developments

Currently in the market there are quite a few products aimed towards enhancing a consumer's experience when owning pet fish. Although one thing that can be observed is that each product only serves to enhance only a couple things when it comes to taking care of fish. Whether it is to help with simple maintenance or even notify you of the smallest details of your miniature ecosystem, it always feels like there's something more you can add. As we looked through other related products or inventions it either was too expensive or lacked the stability for long-term use.

An example of a product that is currently out in the market is ‘Glass Aqua’ which presents the slogan of “Aquariums meet Technology”. This product allows for the creation and continued maintenance through the innovation of devices that allow for the integration of technology with aquarium care. This product truly does wonders for the consumer experience with the easy creation of a tank that has both the aesthetic and functionality to keep your fish healthy and happy. As this is one of many products currently out on the market, it unfortunately falls under the functional yet expensive side of the spectrum which makes it difficult for the average consumer to be able to utilize this product to the fullest.

Furthermore, there are other products in the market today besides ‘Glass Aqua’ that already include these innovations such as a smart aquarium system that provides monitoring to alert for any irregularities, or even tanks with built in innovative devices that can feed, and even filter the water through the tap of a button on an app. The product names we found that included some if not all were Maxspect Lagoon, Fluval Flex, Xiaomi Smart Fish tank, etc.

Through a past senior design project that we found, it provided a lot of what we also wanted to add to enhance the experience of owning your very own fish. It included many different types of technology that ‘Glass Aqua’ and other products may or may not use but at a more reasonable yet efficient rate. With further research and analysis through the findings and designs of both the senior design project and existing products, there was still more left to be desired that we as a group want to capitalize upon by being more innovative with what we add but also enhance further the type of product that was previously created.

As we dive further into our research, we understand that what we are creating isn’t anything that hasn’t been seen before. We want to take what is an obvious technological addition to a fish tank aid and design our own version that gives much more practicality in the maintenance and longevity of aquarium care that won’t break a budget and still provide everything that a consumer will need through a simple press of a button.

2.0 Goals and Objectives

Overall Goals:

- Provide a comprehensive system for managing an aquarium, ensuring the well-being of the fish and ease of use for the owner.
- Maintain optimal water conditions.
- Automated feeding.
- Ensure effective monitoring and control.

Basic Objectives:

- Implement a PH sensor to accurately measure the water's PH level.
- Integrate an automated food dispenser to ensure fish are fed at scheduled intervals.
- Continuously monitor water temperature using a temperature sensor to ensure it remains within a suitable range for fish health.
- Incorporate a PH solution dispenser to automatically adjust the water's PH level based on sensor readings.
- Use a Raspberry Pi to control a smart lighting system that simulates natural light cycles and enhances the tank's aesthetic appeal.
- Include a turbidity sensor to monitor water clarity and detect any quality issues.
- Develop an intuitive mobile application for remote monitoring and control, allowing users to manually override automated systems.

Stretch Goals:

- Integrate a live feed camera to provide real-time video of the fish tank, allowing for remote monitoring.
- Implement an air bubble system controlled by a Raspberry Pi or PCB to enhance water aeration and improve oxygen levels.
- Create a comprehensive analytics dashboard that logs historical data of all monitored parameters and implements alert notifications for critical conditions such as PH imbalances and temperature extremes.

By achieving these goals and meeting the design requirements, the Tank Pack will provide a comprehensive solution for maintaining a healthy and thriving aquarium environment.

3.0 Description of Features/Functionalities

After researching the available "smart" aquariums on the market, we found that none offered an automatic pH solution dispenser or a combination of

temperature, pH, and turbidity sensors. Some auto feeders included a live stream camera, but like temperature sensors, were sold as standalone products. Among the smart aquariums found, these would only offer a self-cleaning system or basic smart lighting capabilities limited to simple color selections. In general, we could not find a product that included a combination of all the features above and no product included a turbidity sensor or an auto dispenser of pH solution.

In Spring 2020 – Summer 2020, a senior design team created AquaEco. This iteration of a smart aquarium offered an automatic feeder and sensors for checks of the water's temperature, pH and turbidity level and RGB lighting, which allowed the user to manually select a color. Although this is an impressive project, it lacked features such as live streaming functionality to monitor the tank's activity when the user is away from their house, automation of a pH dispenser, bubbles system or utilizing the smart lighting feature as a visual cue to indicate the quality of the water. With the comparisons of current products in the market and past senior design projects, we were able to choose a set of features to implement in our version of a smart aquarium as follows.

3.1 General

- The enclosure for the feeder enclosure will be constructed via the 3D printing material PLA since it’s cheap, easy to use, and compostable polymer.
- The enclosure will house the required electronics, fish food and pH solution.
- A cutout on the enclosure will provide a spot for the camera to capture a livestream. It will be positioned against the tank’s glass for a clear view of the fish activity.

3.2 Hardware

- A custom PCB will be powered via DC power and will act as the main board that drives the needed inputs and outputs of the connected components.
- A Raspberry Pi board will power the camera to be used for the livestream of the fish tank. This board will be connected to the main PCB providing the footage.
- There will be a Wi-Fi module connected to the custom PCB which will provide the necessary data to the mobile app and allow remote controls.
- A motor, powered by the PCB, will be used to dispense the fish food.
- A temperature sensor will track the water’s temperature.
- A pH sensor will keep track of the water’s pH level which will trigger the Ph solution dispenser as needed.
- A servo motor, powered by the PCB will be connected to an IV bag roller clamp which will control the amount of pH drops dispense into the water.

- A turbidity sensor will keep track of the water's quality triggering a smart lighting system along app notifications informing the user it's time to replace the water.
- There will be a water pump connected via USB to the Raspberry Pi board which can be manually turned on/off via the mobile app or automatically turned on/off based on a schedule.

3.3 App and UI Integration

- The mobile application will focus on easy-to-use, featuring a modern interface, which will allow the user to control the smart capabilities of the fish tank. For example:
    - Smart Lighting System
    - Food Dispenser
    - Ph Solution Dispenser
    - Bubbles System
    - Livestream Camera Access
    - Set Schedules

- Notifications:
    - Notification sent when the feeder dispenses food.
    - Notification sent when the pH sensor detects the Ph level is below or above optimal conditions.
    - Notification sent when the pH dispenser adds the solution to the water if it's found to be below optimal conditions.
    - Notification sent when the turbidity sensor detects the water quality is below optimal conditions.
    - Notification sent when the water sensor detects the temperature is above or below optimal conditions.

4.0 Engineering Specifications & Requirements:

The table below lists our project's specifications that shows clear metrics for testing and assessing success. We will prioritize maintaining these specifications by thoroughly testing the prototype and final product.

Please note that these specifications are subject to change given our limited experience with large-scale projects such as this. We also included the overall project budget to further emphasize and highlight the importance of balancing cost-effectiveness with performance standards.

While each component has specific requirement that are crucial for maintaining optimal conditions for aquatic life, we chose to highlight the sensors, water pump control and servo motor control to illustrate how these components work together to support the health the stability of aquatic environment.

Specification	Criteria
Power Supply	Wall outlet power
Max Power Consumption	<50 Watts
pH Sensor Response time	Response Time: ≤ 2 min
Temperature Sensor Response time	Response Time: ≤ 2 min
Temperature Sensor Accuracy	Temperature must be between 50-100℉
pH Sensor Accuracy	pH level must be between 7.6 and 8.4
Turbidity Sensor Accuracy	<2 NTU
Food Dispenser Accuracy	Food Dispenser must dispense between 2 oz – 4 oz
pH Dispenser Accuracy	pH dispenser must be between 0.99 mL – 1.01 mL
Dispensers Capacity	5 oz - 10 oz
Live Feed Camera Resolution	1080p
Air Bubble Power consumption	2 Watts ≤ 5 Watts
Motor Response Time	Response Time: 1ms
Cost	<$500

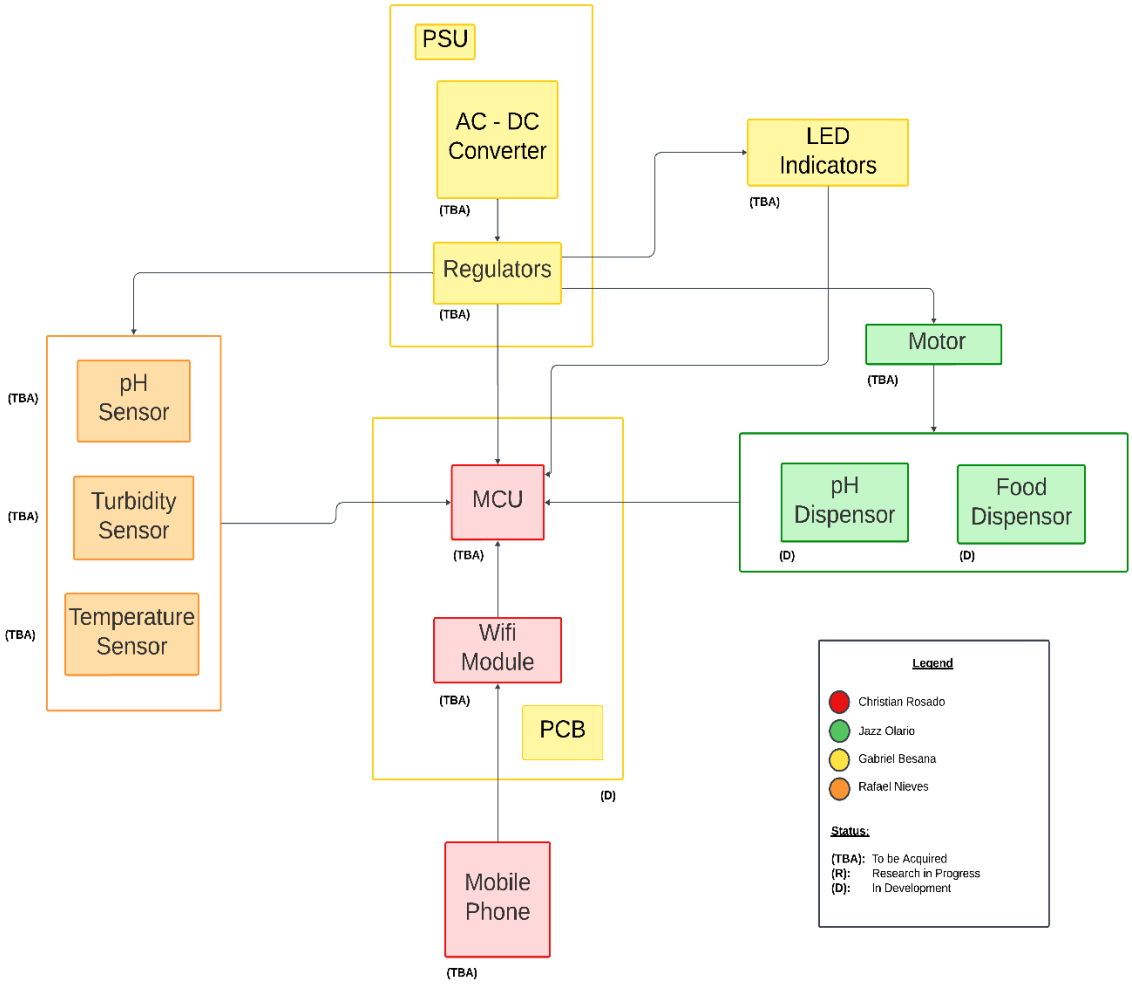
For Demonstration:

- *Food Dispenser Accuracy*
  - Ensures proper nutrition for aquatic life at are crucial for their health and prevents diseases.
  - Dispenser Accuracy must be between 2 oz – 4 oz for food and 0.99 mL – 1.01 mL for pH dispenser
- *Temperature Accuracy*
  - Ensures timely detection and changes of water temperature, which is vital for prompt actions to maintain the ideal temperature for the aquarium.
  - Temperature must be between 50-100℉
- *Motor Response Time*
  - Allows precise control of the IV bag roller for maintaining the desired pH levels in the water.
  - Response time must be 1ms to clamp silicon tube to ensure the accuracy of dispensing pH solutions.

5.0 Hardware diagram/flowchart

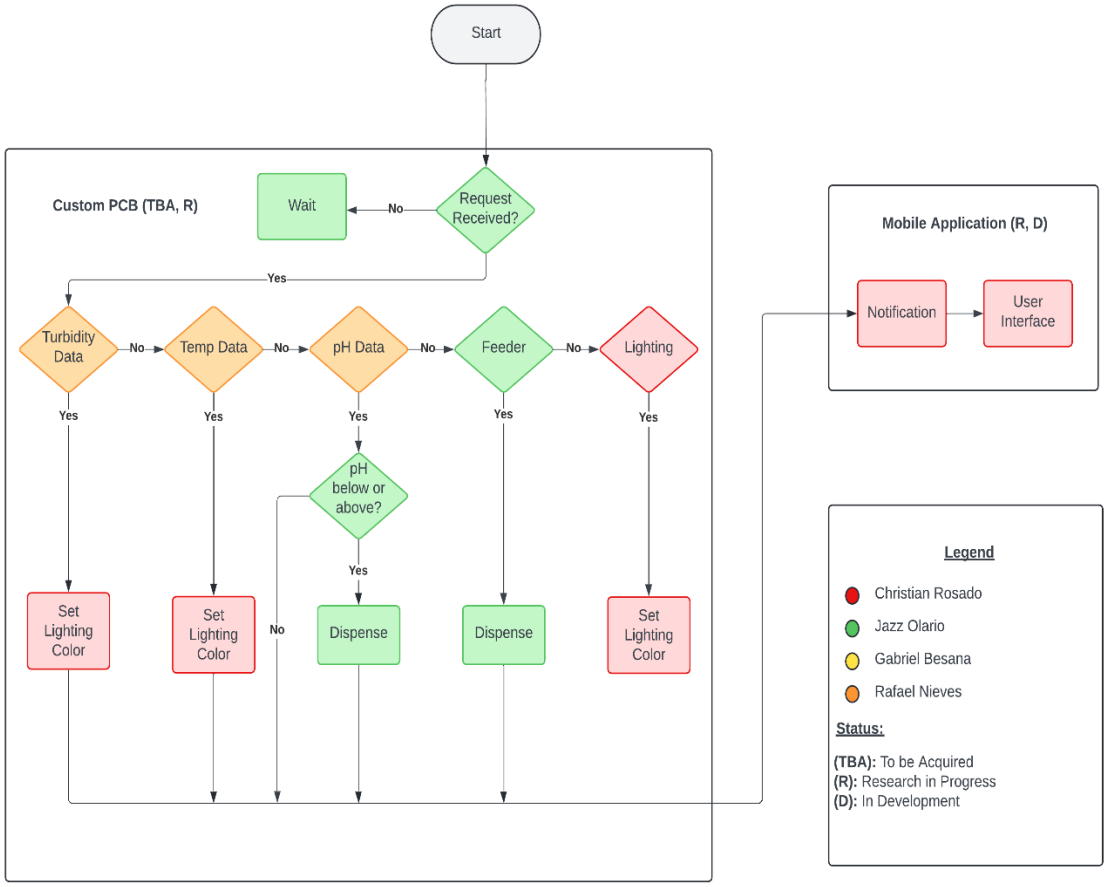
The figure below shows the block diagram that we as a group designed to provide an adequate visual representation of the aspects of hardware that we will include in the project. Our goal is to have a system where we can have clear and concise

interfacing and communication between the components. With the power supply unit, it will supply the necessary power to the main components which include our sensors, dispensers, Rasbery Pi, and microcontroller. The main purpose of the diagram is to present the roles that each member of the group will have within the creation of this design. Lastly, this diagram shows the specifications that we have set to meet the overall requirements.



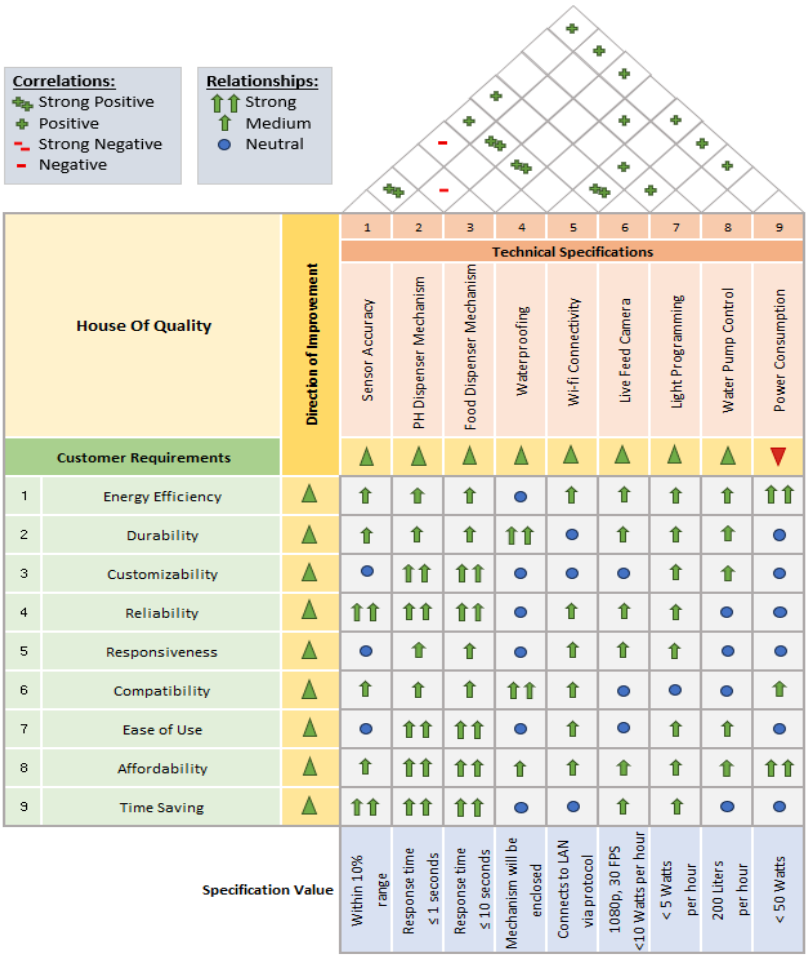
5.1 Software diagram/flowchart

The figure below is the software flowchart/diagram which provides a visual description of the smart aquarium's functionality. It's divided into three blocks: the PCB software, Raspberry Pi software and the companion mobile app. The accompanying legend indicates the work distribution among team members, as well as the status of each block in the diagram, providing a clear overview of the project's progress.



6.0 House of Quality

The House of Quality outlines the relationship between customer requirements and technical specifications. Strong positive correlations indicate that improving one aspect can significantly enhance customer satisfaction. For instance, maximizing sensor accuracy (strongly correlated with accuracy, reliability, and automation) and ensuring robust Wi-Fi connectivity (vital for responsiveness and automation) are critical. Power consumption is to be minimized to enhance affordability and energy efficiency. The relative weights of each technical specification reflect their overall importance, guiding the design focus towards features that will most effectively meet customer needs and expectations. By analyzing the House of Quality, the design team can prioritize efforts and resources effectively. Features that show strong positive correlations with key customer requirements are given priority. This approach ensures that the design and engineering efforts are aligned with what customers value the most. This matrix helps ensure that the final product not only meets but exceeds customer expectations by focusing on key areas that drive satisfaction.



7.0 Budget and Financing

The table below is a rough estimate of the budget. It covers all the essential components for our project's successful implementation. Each component plays a crucial role in the overall functionality and effectiveness of the project.

Note that the overall budget includes the primary components and accounts for the additional costs. This allocation ensures that we can acquire the required materials while effectively managing costs, which enables us to maintain the balance of affordability and quality.

Budget and Financing	
Component	**Estimated Price**
pH Sensor	$20
Temperature Sensor	$10
Turbidity Sensor	$10
Dispenser(s)	$20

Budget And Financing	
Component	**Estimated Price**
Air Bubble	$20
LED Lights	$15
Raspberry Pi	$15
Camera Module	$20
Motor(s)	$30
PSU	$20
Custom PCB	TBD
	Cost = $180

8.0 Project Milestones

With the established due dates, our goal is to follow this time frame as closely as possible. Most of these milestones are paper drafts throughout the semester. While most of our research will be conducted to Senior Design 1 for data collection and conceptual development.

Initiating PCB design and developing the front-end application during this semester would also help us prepare for the tasks ahead in Senior Design 2. It might be difficult to achieve this milestone, especially for the summer semester with limited time to complete it. However, attempting or achieving this milestone will undoubtedly enhance our progress significantly.

Senior Design 1		
Overview	**Description**	**Planned Duration**
Group formation	Identify group members and define individual roles	1 week
Project ideas	Come together and come up with project ideas	1 week
Divide and conquer	Start writing 10-page proposal for approval	1 week
Divide and conquer submission		Due 5/31/24
Research and planning	Begin writing 60-page document draft	4 weeks
Review draft	Review and revise draft based on feedback from peers and reviewers	1 week

Senior Design 1		
60-page draft submission		Due 7/5/24
HW & SW design	Initiate PCB design as well as the develop front-end application development	1 week
Finalize and review report		1 week
120-page final report due		Due 7/23/24

The planned duration for the Senior Design 2 milestones is based on Fall Semester and will remain unpredictable. Even so, we have our project foundation all set along with a clear direction for our main idea. As we approach the start of Senior Design 2, our focus is on thorough preparation.

PCB design and App Development is crucial for our project's progress. An early completion of these milestones will certainly help with our progress and possibly ensuring our team to be ready to meet any challenges ahead for Senior Design 2.

Senior Design 2		
Overview	**Description**	**Planned Duration**
PCB Assembly	Building the PCB	4 weeks
Develop Application	Develop and integrate front-end application	4 weeks
Test Sensors & Dispensers	Test sensors & dispenser accuracy and Responsive	2 weeks
Test application	Test user interface responsiveness and ensure reliability of notification-based sensors	2 weeks
PCB Assembly & App Development	Ensure that hardware and software are communicating properly	4 weeks
Debug & Test	Identify and resolve issues in both hardware and software components	2 weeks
Finalize Paper		1 week
Review		1 week
Final Paper and Demo		TBA