VEGILAB and Aquaponics Indoor Growing System

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***Abstract* - A multidisciplinary senior project team consisting of five students from Design Engineering Technology (DET) and Manufacturing Engineering Technology (MFET) have been tasked to design and fabricate an indoor growing system using the VEGILAB technique and Aquaponics system. The project involves a collaborative effort between our university and a Japanese company, the project client. The Japanese company is responsible for funding the project and in turn will obtain the intellectual property rights to the project.**

Due to a constantly increasing world population, a decrease of farm land, climate changes, and food safety concerns, many companies have gotten involved in plant factories that grow certain crops regardless of the weather or environment. The Japanese company, our client, has been expanding the business to include a plant factory called VEGILAB. The VEGILAB is an indoor system that grows vegetables, such as lettuce or tomatoes, in minimal spaces using LED lighting. In conjunction, Aquaponics is another well-established sustainable system that is used for growing plants and fish at the same time.

Existing systems that combine these technologies must overcome some fundamental issues: unattractive design, expensive manufacturing costs, limited grow options, and food quality control. Our senior project team will design and manufacture a new, aesthetically appealing and innovative system that is a combination of the VEGILAB technique and the Aquaponics system which can be used in industry and at home.

Students will spend the first semester, fall 2013, researching, planning, and designing the system. In the spring of 2014, students will be involved in the fabrication and testing of the system. Faculty members from other institutions with experience in Aquaponics will provide additional advisement on the project. Upon completion of the project, the system will be shipped to Hawaii for a formal presentation to the client.

I. INTRODUCTION

Producing enough food supply has become one of the serious issues due to increasing population and decreasing of farm land in the world. By 2050, the world population will be at least nine billion and food demand is accelerating at a far faster rate than population growth because we are eating more food, more people are eating differently, especially more meat, and eating has become a recreation [4]. Because of climate change, producing crops steadily is a difficult thing to do. There are many safety concerns for food because of environmental issues and chemicals such as pesticides. A growing number of people are questioning about what they are putting in their bodies: how it was raised, who raised it, and how it was delivered to grocery stores. More consumers want to know if they are eating the safe foods [5]. Due to these concerns, indoor growing systems became popular and many companies have started to look into the home and commercial size systems.

A Japanese company, Horimasa International Co., Ltd is one of the companies who started investing into this type of technology and their division is called "VEGILAB", which uses LED lights to grow plants and vegetables such as lettuce indoor within limited space. There are various kinds of existing indoor growing systems, however; they have the similar looks which is unattractive. Horimasa International Co., Ltd has been expanding their VEGILAB division by adding Aquaponics technology, which is a research project collaborating with the University of Hawaii and the goal is to develop commercial and small scale urban Aquaponics systems. Horimasa International Co., Ltd has agreed to collaborate with Weber State University to produce a prototype that is a combination of VEGILAB system and Aquaponics that is more aesthetically appealing and can be used for home and commercial purposes in the future.

The Engineering Technology Department at Weber State University formed a senior project team of six students: two from Design Engineering Technology program (DET), three from Manufacturing Engineering Technology program (MFET) and one from Electronics Engineering Technology program (EET). Students applied their knowledge and skills to design and develop a real-world application using LED lights and Aquaponics technologies.

II. RESEARCH, DESIGN, AND FABRICATION

Each member of the team came up with a few ideas and designs for this project. They went through the brainstorming sessions and chose a few preliminary designs. The Aqua-Life, Figure 1, shows the rendering of the final preliminary design that was chosen by the client.

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Figure 1. Aqua-Life

This project involved a feasibility study of the design and fabrication of a product that would integrate plants growing system with LED lights and Aquaponics system with aesthetical elements. One of the main tasks accomplished during the research phase involved the creation of concept drawings for the overall structure and for each subsystem to provide a general perspective on the scope of the project. Costs and availability of major system components that would be needed to develop the system were investigated during this phase. Preliminary mechanical analysis on the frame, panels, fish tank, sump tank, bubble wall, electronic elements, and grow bed was performed to verify structural integrity of the overall system.

The initial research also involved the development of an engineering plan detailing a preliminary budget for the design and build phases.

The Aqua-Life research phase resulted in the development of an extraordinary multidisciplinary design and build capstone project involving two Engineering Technology faculty members and six senior students from the Engineering Technology Department. Students from three different programs participated on a cross-functional team. Each student was responsible for the design, analysis, fabrication and build, as well as the system integration of their specialization. In the course of two semesters, research efforts were completed, the system design was finalized and the Aqua-Life project was constructed, and is now fully functional.

III. FUNDING AND BUDGET

The Aqua-Life project was fully funded by the client, Horimasa International Co., Ltd. $10,000 was available for the construction of Aqua-Life. The client also funded $5,000 for traveling for the team to present the final product in Hawaii in May, 2014. Each student was responsible for researching the necessary material to build this product within the amount of $10,000 during the project research and production phases. Each student was successful in meeting this budgeted amount by using on-line sources and contacting local companies who have helped the school in the past. The total cost was $8,187.31. Refer to Table I. for more detailed component specifications.

TABLE I. AQUA-LIFE BUDGET

PROJECT COST	
assembly	**UNIT PRICE**
Frame	$ 882.54
Plastic Sheets	$ 1,228.77
weld-on #4 & 40	$ 132.22
Fish Tank	$ 714.87
Bubble Wall	$ 800.95
wood Panels and paint	$ 169.27
SS Shell Panels & Sheets	$ 629.27
Heating Strip	$ 284.49
Float switch's	$ 84.65
Connection fitting	$ 40.91
single flute EM	$ 72.49
air compressor	$ 30.00
Water Pump	$ 70.00
Grow Media	$ 74.39
Bio Media	$ 40.00
Float Value	$ 35.68
Valves & Connectors	$ 119.30
Bubble Wall Parts	$ 50.08
Power cord	$ 46.65
LED flex strip	$ 81.19
LED grow light	$ 111.00
Ultra flex	$ 39.89
Channel relay	$ 59.96
Mouser	$ 458.67
Box & Cables	$ 91.72
Mouser	$ 228.14
Tank LED Lights	$ 81.19
Cash Misc.	$ 551.29
Shipping supplies	$ 132.21
R&D misc.	$ 23.25
Team Shirts	$ 222.27
Presentation Room	$ 600.00
SUB TOTAL	$ 8,187.31
Budget	$10,000.00
Budget Leftover	$ 1,812.69

Through a build/buy analysis, the team determined that outsourcing the cutting frame pieces of T-slot and laser-cutting stainless steel sheets for paneling was more time and cost effective. The school had limited machining feasibility and availability. Some local companies gave discounts on some materials and those processes. Otherwise, the team fabricated everything else themselves at school machine shops by spending of 1,000 hours approximately.

IV. THE SYSTEM

The Aqua-Life was designed to accommodate indoor conditions and applications. The total product weight is approximately 1200 pounds and is designed to be on a flat surface. Minimal time and effort are required to deploy the Aqua-Life and prepare it for use. Initial design criteria specified that the deployment process take no more than 4 hours for two people to complete the entire setup or storage routine.

The system includes main components of a frame, sump tank/filter tank, grow bed, bubble wall, fish tank, and the controller panel.

The aluminum frame is constructed of T-slot, 40mm series, 8020 extrusions that were cut into specific sizes. There are total of 41 pieces that are assembled with brackets and bolts. The bottom of the frame has four leveling feet to adjust height and keep balance of the product depending on the condition of ground surface.

The system consists of a fish tank, a sump tank/filter tank and a grow bed where the plants will take in nutrients. The fish tank size is 753 mm x 355 mm x 793 mm and holds about 197 liters (52 gallons) of water. It can hold about 6 fish. The filters are on either side of the sump tank in one enclosure and are both 4.5 liters (1.2 gallons) each. The first filter receives water directly from the fish tank and separates the solids via radial filtration. The water changes direction in a cover pipe and solids settle to the bottom to be collected later. The solid free water is then directed into a bio-filter with kaldness k1 media to cultivate beneficial bacteria. The sump tank maintains an approximate 19 liters (5 gallons) of water to be emptied into the grow bed via gravity feed at a constant rate. The grow bed is approximately 38 liters (10 gallons) and uses a bell siphon to time a flood and drain method for allowing oxygen into the root systems and preventing the roots from rotting in a constant flow. This whole plumbing system is powered by a 115V 3/8 HP pond pump that runs constantly and directly into the solids filter.

The acrylic sheet of bubble wall is cut to size and modified for the air tube to be installed. It has a bottom plate to seal the water in it and provides a drain. Additional side strips are added for LED lighting and assisted with the structural stability of the wall. The mirrors consist of both the sized acrylic mirror on plywood for mounting to the frame structure. The mirrors are used to hide the structure in the back and aesthetical purposes.

The stainless steel side panels were laser cut by a local company to specific sizes, and the team bent at the needed radius and assembled with the black acrylic sheet. The stainless steel was selected by the client and to show the sleek appearance.

The controller panel was custom built with the following features: 4 Output channels for controlling AC hardware, 6 PWM channels for driving LEDS, Bluetooth Communication, 4D Systems programmable LCD, Arduino programmable MCU, and the supply voltage between 90 and 250 Vac, and Adjustable 3 zone RGB leds. The power cord protective grounding must be connected to ground to avoid shock. Voltage higher than 250 Vac should not be applied to the device. The home screen displays the status of both the fish tank and grow tank water levels by using an indicator on the top left of the screen, and also shows two buttons on the lower right to access the RGB led lights and the hardware, shown on Figure 2.

Figure 2: Home Screen

Touching the Led Lights button on the home screen can navigate the LED Lights. This screen allows to adjust the RGB Led lights by sliding the associated slider for the different zones. The Max button turns all RGB zones to white light or red=255 green=255 and blue=255. The random button selects random values for all RGB zones to change colors as shown on Figure 3. The Off button turns all RGB zones off.

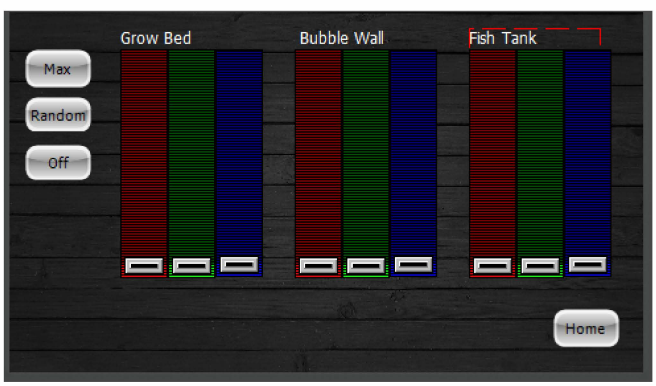

Figure 3: LED Lights Screen

Touching the Hardware button on the home screen will navigate the Hardware screen. This screen allows to manually turn on and off the external hardware, shown on Figure 4.

Figure 4: Hardware Screen

The assembling manual that was created consists of a 54 page step by step process on building the Aqua-Life system. It shows the special features, like the bubble wall and how to install the filtering system. It will teach the user how to use the lighting system as well.

V. APPLICATIONS

Figure 5 shows the completed Aqua-Life system. Future applications of the Aqua-Life can be explored and considered for production for home and commercial services. This system would provide a long-term sustainable solution. The Aqua-Life also offers the advantage of being a clean and quiet system.

Demonstration of the Aqua-Life is planned at the Science Park in Hong Kong, and overall mechanical and electrical performance will be evaluated to determine if any modifications need to be made to the system by Horimasa International Co., Ltd.

Figure 5: Completed Aqua-Life System

VI. OUTCOMES

The Aqua-Life research project involved students from three different engineering technology programs working together on a multidisciplinary project, where they were able to achieve success on an individual level and as a functional team. Now there is a fully operational system.

Students went to East Meets West Aquaponics Symposium in Hawaii on the 10th of May, 2014 to present this product to the client, faculty and staff members from University of Hawaii, and people how are interested in Aquaponics. The symposium was very successful. The client was very impressed with this final product, which was shipping to their office in Science Park in Hong Kong.

Students have benefitted from extended research projects on various mechanical and electrical aspects of the Aqua-Life system. Future research can involve the integration of solar power supply to be more sustainable.

VII. ACKNOWLEDGEMENT

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