Controlling and monitoring of aquaponic system

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***Abstract*—**The aquaponic systems popularity has gradually increased over the last several years. The idea of cultivating provisions is an appealing as well as a satisfactory way or to improve one's life quality. The system, however, requires almost constant monitoring to ensure the proper state of flora and fauna. The issue of profound time consumption impairs the user's possibilities to optimize the function of the system. To compensate for this inconvenience, the solution discussed in this paper covers methods to develop automated controls that can be accessed using the internet. There are multiple options to approach this, although they are cost intensive. Our approach will provide a comprehensive solution for under 250 €.

Keywords—Aquaponics, Ecosystem, Controls, Food, Monitoring.

I. INTRODUCTION

The history of aquaponic systems reaches over a thousand years back. The first agricultural environments were made by Aztecs as well as by Far-Easter Countries such as China or Thailand[1].

Currently, those units vary in sizes and scopes of species inhabiting them. The market is filled with small household products as well as semi-industrial ones allowing to cultivate profound amounts of ecological food. The growing popularity of those solutions uncovered several issues that impede the efficient use of the aquaponic systems *e.g.* supplied water quality, choice of soil to be applied as well as the monitoring and controlling of such a unit.

Generally, the most profound obstacle for the system to be applied in household is the amount of time required to properly manage it. Artificial environment as such needs constant monitoring in order to ensure plants and animals well-being that in result guarantees best quality of obtained food. The solution to that problem is currently being in development and two approaches are applied. First manner are the whole setups containing the monitoring and controlling systems as well as the tanks suggested fish and plants species are made. An alternative way are the universal control units possible to apply to almost any aquaponic environment.

The aim of the research conducted during the project was to develop the controls using the latter approach and keep it affordable without losing essential functions. The our product - *Aquaponic Admin* is aimed to be affordable, efficient and sustainable.

This paper consists of four main sections.

- In state of the art there are general guidelines concerning aquaponic system development as such, as well as, similar products already present on the market.
- In the methods section there are development process and technical details concerning the product presented.
- Tests and results are aimed to show how the prototype fulfills previously prepared requirements.
- Discussion, contains the conclusion of the whole process and future development possibilities and ideas.

II. STATE OF THE ART

Several functionalities of the control system must be present for it to be applicable in aquaponic setup[2]. They were based on the systems available commercially and are presented in the **Table 1.**

Table 1: The requirements for aquaponic control system

Monitoring features	Control features	Remote access options
Required		
Temperature sensing	Temperature setting (heater)	Remote monitoring and control
pH sensor	Pump toggling	Web or mobile application
Flow sensor		E-mail/Text message/Phone call notification
Water level or leak sensor		
Optional		
Conductivity sensor	Fish feeder	Live video streaming
Video camera	Switchable light	Histogram from sensor feed
Food level monitoring		

It is valid to note that none of the systems reviewed offers all of those options. As presented in **Table 2**, each of them contains unique features while omitting several optional ones.

Not only it was aimed to include essential functionalities in developed product it also was required to fulfill guidelines concerning energy and sustainability as well as ethics and deontology.
In the energy and sustainability case, one of the ground rules to obey was to minimize energy consumption of the product, which was obtained by applying low-voltage working components as well as structuring microcontroller code in such a way it turns on sensors, stepper motor and relay connected devices only when necessary. Another prerequisite for the device was to be user friendly and require low maintenance, in that case the quality of components was essential. The more expensive, original subsystems were applied instead of cheap unreliable replacements. With the user-friendliness issue, the solution was creating additional precautions in code *e.g.* if the given threshold of temperature were to be crossed the heater would be turn off automatically.

Table 2: Functionalities comparison of aquaponic control systems available on the market as well as the ones designed for *Aquaponic Admin*

	OSMOBOT	**KIJANI GROWS**	**SENSAPHONE 800**
pH sensor	Yes	Yes	No
Temperature sensor	Yes	Yes	Yes
Flow sensor	No	Yes	Yes
Water level	No	Yes	No
Food dispenser	No	Yes	No
Video camera	No	No	No
Remote monitor	Yes	Yes	Yes
Remote control	Yes	No	Yes
Light	No	Yes	No
Email/SMS/WEB/Phone call notify	Yes	Yes	Yes
Price [USD]	499 +	205-690	995
	SENSAPHONE 400	**OPEN AQUARIUM**	AQUAPONIC ADMIN
pH sensor	No	Yes	**No**
Temperature sensor	Yes	Yes	**Yes**
Flow sensor	Yes	No	**Yes**
Water level	No	Yes	**Yes**
Food dispenser	No	Yes	**Yes**
Video camera	No	No	**Yes**
Remote monitor	Yes	Yes	**Yes**
Remote control	Yes	No	**Yes**
Light	No	No	**Yes**
Email/SMS/WEB/Phone call notify	Yes	Yes	**Yes**
Price [USD]	749	299	UNDER 280

When the matter of ethics and deontology is concerned, the main issue was to provide the fish with comfortable environment and to ensure proper nutrition and conditions to live would be fulfilled. Taking care of living organisms always requires additional caution. The special focus was given to ensure the all electric wires are going to be waterproof and protected from the damage to avoid electrocution, what is more, the feeder, pump and heater are monitored and controlled in order to avoid harming the fish *e.g.* by overheating water.

III. METHODS

The whole product development was initiated by the need to design efficient, reliable and cost-effective aquaponic system controls. With the budget of 250 € the complete product was to be developed. The key features needed for it were as follows:

- use of low cost hardware solutions;
- use of open source and freeware;
- include controllable food dispenser;
- adopt the International System of Units;
- include a camera, temperature and flow sensors;
- be compliant with the Machinery EU Directive (MD), Low Voltage EU Directive (LVD) and Restriction of the use of certain Hazardous Substances (RoHS) EU Directive.

The initial part of the development concerned the choice of applied components, the decision between web-based and mobile application and dilemma whether to use LCD screen in the whole setup.

The final decision concerning the parts was dictated by several factors:

- price;
- availability of the libraries and open-source examples using that pieces of electronics;
- additional amenities allowing to fix them easily;
- being waterproof;
- complying to the RoHS norm;
- compatibility with Arduino and Raspberry Pi that were chosen as first devices.

The choice of Arduino and Raspberry Pi was dictated by several factors. Most important of those were:

- For Arduino:
  - Broad range of available compatible devices;
  - Simplicity of programming language;
  - Serial port communication between the microcontroller and superior unit.
- For RasperryPi:
  - Built in Ethernet card and support of Wi-Fi dongles;
  - Compatibility with video camera;
  - Simple, Linux-based operating system.

The rest of chosen components is being presented in **Table 3**.

Table 3: Components applied for final prototype

Component	Main features
300 K Pixel Mini Webcam	Easy to connect to Arduino, compact.
Pi Tin Clean (Wi-Fi module)	Economical Wi-Fi dongle.
G1/2 Water Flow sensor Model PTR001426	High flow volume capacity.
Ultrasound Sensor HC-SR04	Economical, with accuracy proper to checking water level.
Daily Double II Automatic Fish Feeder	Easy to modify and connect to stepper motor.
Light LED 6 W 4200 K	Low energy consumption, low working voltage.
Power Supply 12 V DC 1.4 A EU	Low power consumption.
DS18B20 Digital temperature sensor	Waterproof, uses less energy than similar.
Infrared shooting sensor	Perfect to check the presence of the food in the feeder.
Stepper motor with converter	Allows precisely defined number of rotations, low working voltage.

The next phase of the development was setting up the database and making of the web application to control the *Aquaponic Admin*. It consisted of several PHP functions.

PHP is a server side language meaning it is intended to communicate with data servers. For the application it was simple to retrieve stored data from the Raspberry Pi, and upload it to a database then retrieve that information on a webpage with PH. PHP is beneficial in that it works well with a MySQL database

After that, the Arduino-based sensor controls were developed. Most of the code was based on pre-made libraries such as Dallas Temperature or IRremote. The main function of Arduino was to receive and process sensor inputs, as well as, to control relay, to which the lamp, pump and heater were connected. The general requirement for the code was to turn on the sensors and devices only when necessary in order to avoid additional current losses and, in result, increase device eco-friendliness.
The Arduino served as a Slave device, it was controlled by Raspberry Pi through serial port. The Raspberry Pi itself was responsible for receiving user input from website, transferring commands to microcontroller, while receiving sensor data and writing them to database.

The last part of product development was setting up ready product. The simulations of it are presented in **Figures 1** and **2**.

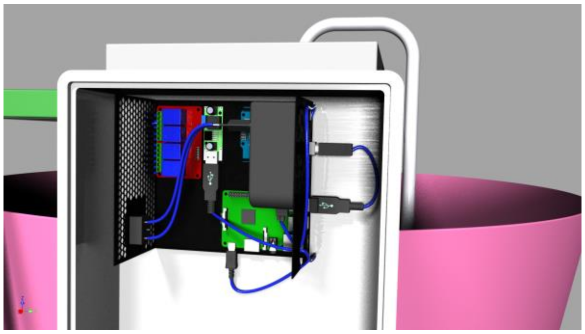

Figure 1: The control system assembled and fixed to tank

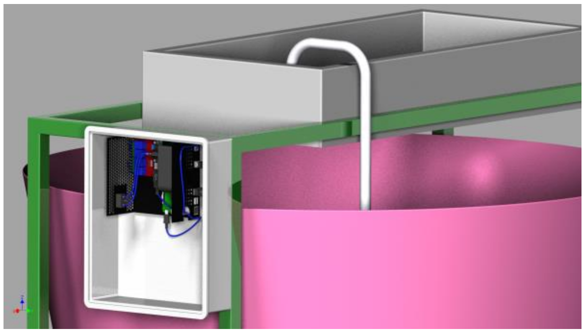

Figure 2: The overall view of control box, fish tank and plants bed

The basic requirement for assembly was to keep all the parts as close to control units as possible in order to minimize interferences that might occur on the wires. The heater was put at the bottom of the tank in order to maximize efficiency of water heating. The feeder was fixed with infrared shooting sensor and placed directly over the tank. The whole system is presented on the **Figure 3**.

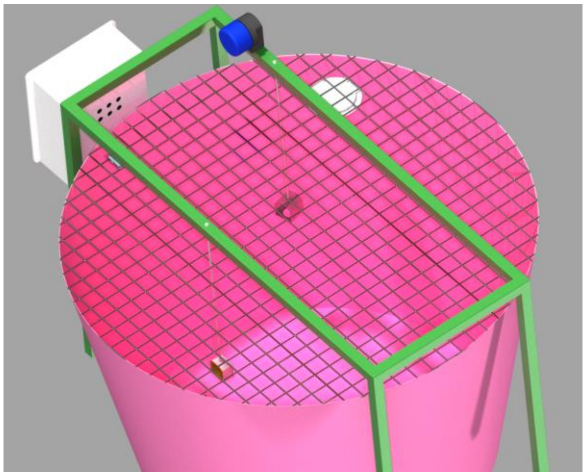

Figure 3: The whole assembled system without plant bed

IV. TESTS AND RESULTS

For the testing part a series of experiment aiming to determine system proper work was developed. The main functionalities to test if working properly were the proper turning on and off of all the sensors and devices connected to Arduino, automatic turning off of the heater as soon as the temperature reaches defined threshold, proper communication between Arduino and Raspberry Pi through the serial port, appropriate writing to and reading from the database, web application input being realized properly. The complete tests list is presented in **Table 4**.

The main functions of the system were confirmed to work properly. The only issues encountered occurred initially with video stream to the website and infrared sensor not working properly, however they were resolved.

Table 4: Functions and tests for the system

Function	Test
Access webpage	Confirmed
Register webpage	
Login webpage	
View check status	
Page updates	
View change status page	Confirmed
Change page	Confirmed
Update database	
Video stream	Access on webpage
Power	Confirmed
Pi boots and runs application	Confirmed
Pi and Arduino Communicate	Confirmed
Flow sensor	Arduino reads correct value from sensors
Temperature sensor	
Infrared shooting sensor	
Depth sensor	
Light	Arduino turns the devices on and off
Pump	
Feeder	
Heater	

V. DISCUSSION

The work on the project can be concluded from different approaches. The first one is from the group work point of view and team experience.

In that case, all of the members learned something outside of their field of expertise, each person had to understand different phases of product development. It also improved the communication and work management skills. Working in the multicultural group influenced the approach towards the final outcome of the project.

On the other hand, from the product-oriented point of view, the project turned out to be challenging yet rewarding and feasible task. The device fulfills given requirements and its development didn't exceed the budget.

There is also the space for future development, either including higher tier Arduino and introducing the more sensors *e.g.* pH and conductivity ones. What is more the dedicated mobile application containing more options allowing personalization could also be developed. Last but not least, the moving camera could also be introduced to be able to control whole tank using video feed.

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