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IOT BASED SMART AQUAPONICS SYSTEM WITH FUZZY BASED DECISION MAKING SYSTEM AND MACHINE LEARNING BASED PREDICTION

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ABSTRACT

Aquaponics is an emerging area in food production method which combines traditional hydroponics with aquaculture in a symbiotic environment that facilitates a sustainable system with necessary input as all the water and nutrients within are re-circulated in order to grow terrestrial plants and aquatic life. When aquaponics system meets with technology it seems to produce some remarkable outputs which makes it efficient and productive technology. In Iot Based Smart Aquaponics System with Fuzzy Logic, we take different readings regarding the pH level, temperature, moisture content and the level of the water by using different sensors. Readings from each of these sensors are stored in the server for future use. Also these values are used by the fuzzy controller which controls the overall working of the system in drastic condition. Iot eliminates the gap between the physical world and digital world. In order to introduce technologies to the traditional aquaponics system, we use of Arduino, Fuzzy controller and Internet of Things.

Key words : Aquaponics, Arduino, IOT, fuzzy logic, Machine Learning, SVM, Matlab

1. INTRODUCTION

Aquaponics is a new cultivation technology and so many of us are not more aware about that. It is an emerging technology which combines both aquaculture (rearing of fish) and hydroponics (the process of cultivation of plants without soil) together into a single system. How it is possible? This is a system which includes a fish tank as a part of aquaculture and a growing bed for cultivation of plants. Excreta of the fish are used as fertilizer for the growth of plants. For that, water from the fish tank is passed to the growing bed. In the growing bed, microorganisms present in the roots of plants breaks the toxic contents present in the waste water, purifies it and get pumped back to the fish tank. This is a cyclic process. The problem is that, as it is a cyclic process we have no idea about the quality of water. It does not give any guarantee that the water which gets pumped back into the fish tank is free from toxic contents. If there exist any presence of harmful substances in the water then it results for the death of aquatic animals in the tank. In the paper "IoT based Aquaponics Monitoring System" by Abhay Dutta,[1] they used different features to monitor pH value, temperature and humidity level, water level using the specific sensors has been done and then after perceiving those values from the sensors, the values were displayed through a 16*2 Liquid Crystal Display as well as on the web by the application of Internet of Things. To connect the sensors with the internet, the database server and application server can be managed so as to display the information regarding the sensors. In order to introduce technology to the traditional aquaponics system, they use Raspberry Pi microcomputer and Internet of Things in the system has been done.

In "IoT Fuzzy Logic Aquaponics Monitoring and Control Hardware Real-Time System" by Adnan Shaout and Spencer G. Scott [2], they introduced fuzzy logic for the evaluation of input and to generate their specific output. Instead of Raspberry Pi, they used Arduino Uno R3 board for their hardware. In our paper we are combing Aquaponics system with fuzzy logic and Internet Of Things along with machine learning for decision making. SVM classifier is used as the classifier. Also we are using the same Arduino Uno R3 board as our hardware. Here we use different sensors for reading values like pH value, Temperature level, water level and Moisture content. These values can be monitored by the client (user) over mobile application through Internet Of Things.

The paper aims to design an aquaponics monitoring and control system that is accurate, low maintenance, low cost and convenient. The main objective of this paper was to create a system that removes the trouble of maintenance from the user.

As we mentioned earlier, Arduino Uno R3 board is selected for the implementation of its hardware section. It was found to have drawbacks because of the programming language which we use is abstracted to high level. Therefore we use matlab for better efficiency. Sensors sense the data at every 30secomds. Fuzzy logic is used to evaluate the input and automatically provide the proper outputs.

Figure 1: Simple Aquaponics System

2. LITERATURE REVIEW

Dr. J Rakocy along with his friends started a research in the usage of deep water culture hydroponics grow bed in an extensive aquaponics system and found rapid growth of root in the system. Also they found that the system runs fit with low pH value [3]. Aquaponics is an inexhaustible way for cultivating organic vegetables and fruits without the use of any chemical fertilizers. It is technique which is totally eco-friendly [4].

Aquaponics is one of the developing technologies whose main intention is to reuse the nutrients pulled out by fishes in the fish tank and is utilized for the growth of plants. This will helps to avoid the use of toxic pesticides, fertilizers and insecticides [5]. An Arduino Uno Microcontroller will provide an accurate control over the aquaponics cycle. It will helps us to control the system from anywhere in the world [7].

Wang proposed a method about different sensors and about their controlling. This is an interactive application in which the data is occupied by a webcam. Also as mentioned that this is an interactive method, the users can continuously monitor and control the system.

Arduino is used in its hardware system [9]. Cho Zin Myint and his friends present a new sensor interface device for monitoring the quality of water. It works in an IoT environment. It also include Zigbee based wireless communication module. FPGA (Field Programmable Gate Array) is the core component in his proposed system [10].

3. ARCHITECTURE

Coming to the architecture side we have a fish tank, different sensors, grow bed, embedded section, fresh water tank etc. As we mentioned earlier water in the fish water gets contaminated due to the presence of fish waste material. Therefore we need to purify them for the healthy growth of aquatic lives in it. Also we need to maintain a particular water level in the tank. An ultrasonic sensor is connected with the fish tank which checks the water level which is connected to an Arduino UNO R3. Also it contains other sensors like pH sensor, Temperature and Humidity sensors. Senses read the data in every 30seconds. All the readings are passed into the Arduino board. Inorder to provide more reliability Matlab is used for programming phase.

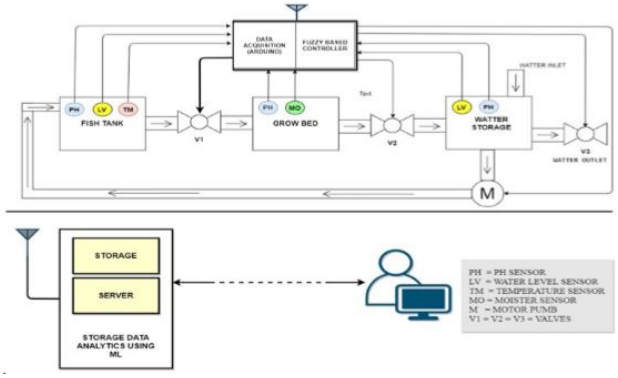

Figure 2: General architecture of the system

At first consider the situation in a fish tank. Sensors read the value of water level, pH and temperature from the fish tank at every 30 seconds. These values are evaluated by fuzzy based controller and the results get displayed in the 16*2 lcd display. Valve is placed outside the fish tank. Whenever the pH of the water is high, a buzzer sound will be produced as the output and a trigger message is triggered to open the valve so the water will flows towards the grow bed for purification. In the same time, ultrasonic sensor senses the water level and if it is below 40% a notification will be send to the user both through the lcd display and to their phones.

Thus the user can automatically give instruction to pump water from the second water tank which has purified water to the fish tank. Plants in the grow bed will absorb the water coming from the fish tank. It breaks down the toxic content present in it thereby control its pH content. Moisture sensor senses the moisture content in the soil. When the amount of water in the soil is below the required value then water is sprayed into the soil. After purification pH of the water is again calculated before leaving them to the tank. Water is allowed to pass in the second tank only it satisfies the required pH value.

Machine learning is an idea to learn from examples and experience without being explicitly programmed. Instead of writing code we feed data to the generic algorithm and it builds logic based on the data given. Working of the system depends on the output of Fuzzy system. Output data gets stored in the server. As the sensor senses the data at each 30seconds, huge amount of data gets stored in the server. Machine learning makes prediction on the basis of this data and makes changes by giving a new rule condition to the fuzzy system.

3.1 Block Diagram

All the values are evaluated by the fuzzy inference system (Fuzzy based controller). Their output from the fuzzy inference system is displayed in an LCD monitor, which helps the user to monitor and to take necessary actions if they are around. Also the values are stored in the server so that the user can also monitor and control the system from anywhere around the world.

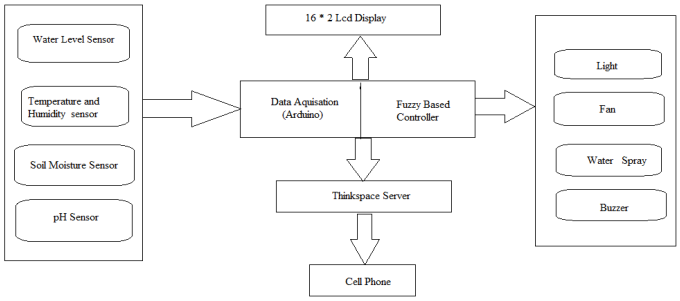

Figure 3: Block Diagram

An LED light (light), buzzer, water spray and a heater is also been placed in the system for representing the outputs. pH of the water from the fish tank will be labelled by 3 membership functions in the fuzzy inference system. It can be acidic, neutral or basic. Most commonly the water from the fish tank will be acidic in nature.

Buzzer will get triggered once when the pH level is acidic and twice when it shows basic in nature. It does not provide any sound when the pH is of required form. Similarly when the temperature of the water and moisture of the soil is also represented using 3 membership functions (high, normal, low). Temperature is controlled using a fan and if the moisture value is beyond the expected value in the soil then it is cleared by using a water sprayer.

For knowing the water level we are using ultrasonic sensors. LED's are used to determine their values. They are represented in percentage. We consider 5 different ranges of membership function for representing the water levels. So when the output is 40% ie., only 40% of water is left in the tank then 2 led lights will glow each indicating 20%.

3.2 Internal Design

Figure 4: Arduino with sensors

Thinkspace server is an open source cloud platform which is mainly used for projects which works with the application of Internet of Things. It will help us to collect and store sensor data in cloud platform. It can also been defined as an application of IoT. Our device or application can communicate with ThingSpeak using a RESTful API, and we can either keep our data private or public. In addition to this, ThingSpeak can also been used to analyze and act on our data. The main use of this application is to collect data from sensors and retrieve it whenever user wants.

The Arduino is a widely used controller board with ATMEL328P microcontroller. It has 20 input/output pins. The Arduino has a widespread support community, which makes it a very easy way to get started working with embedded electronics. The R3 is the third, and latest, revision of the Arduino Uno.

pH Sensor, we can use pH1000 polycarbonate pH sensor. It is sensor which is mostly used in laboratories. They provide reliable and stable readings.

Ultrasonic Sensor (HC-SR04) along with the help of some LED's, we can sense the amount of water present in a tank in percentage. LED's represents the percentage of water in the water tank. Here we are using 5 LED's. Each one will represent a percentage of 20%.

Temperature and Humidity Sensor / module (DHT 22) are very cheap in cost with great performance. It is an advanced version of DHT11. Its temperature measuring range varies from -40 to +125 degree Celsius with 0.5 degree accuracy. It also has better humidity measuring range from 0 to 100% with 2 to 5% of accuracy. DHT22 consist of a humidity sensing component and an NTC temperature sensor or Thermistor an IC for measuring the humidity. The thermistor is a variable resistor that changes the resistance with the change in its temperature.

Moisture Sensor, FC-28 is used to measure soil moisture. It checks the moisture content on the roots of plants which get cultivated in the growing bed. It can be used to save water which is present in grow bed with the help of Arduino. It consists of two parts, a main sensor and a control board. The main sensor board is two-layered that goes into the soil. It also has 2 male headers which are connected to the control board. The control board is an amplifier or a converter which convert analog signal into digital signal. Digital data is controlled by a potentiometer which is in-built in the control board. The output of the sensor will be either 0 or 1. This output is passed into the Arduino. The control board also consist of 2 LED's. Among them one is a power-on LED and the other one works with the digital output pin.

4. EXPERIMENTATION AND RESULTS

According to our project we can conclude it by the following results. Every living thing in the Aquaponics system, whether it be the fish, the plants, or the bacteria, they requires an optimal pH value, Temperature value, water level and an appropriate humidity range for its existence. Therefore continuous monitoring of these values are essential for their survival otherwise it may result for the death of aquatic organisms.

From the project we can find that the ideal pH value required lies in between 6.8 and 7.4. We need to consistently monitor and adjust the pH level to ensure that our system works properly. When pH is low then we need to increase the alkalinity of the water. This can be done by combining calcium carbonate and potassium carbonate in equal amount of water. If pH is high then increase the acidity of the water to reduce the pH value.

Adequate water supply should be there in the system. About 40% of water should be there in the tank else the amount of oxygen dissolved in the water gets lowered which affects the life of fish in tank drastically.

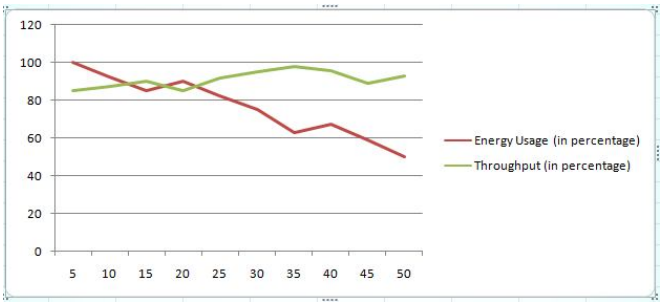

Figure 4: Graph showing energy usage and throughput of the system

Fishes can be categorized into 3 sections; cold water living fish, cool water fish and warm water fish. Tropical fishes can sustain their life with a temperature value of 22-32 degree Celsius. But for cold water fish they vary to 10-18 degree Celsius. Rise in temperature as well as intensity can cause for the solubility of many toxic contents in water. Dissolved oxygen is largely inclined by various factors like pH, temperature and water quality. The optimal temperature required for an aquaponics is the following; for fish it should be 10-32 degree Celsius and the temperature required for the grow bed will be a value around 22 degree Celsius. The relative humidity required will be 45-55%.

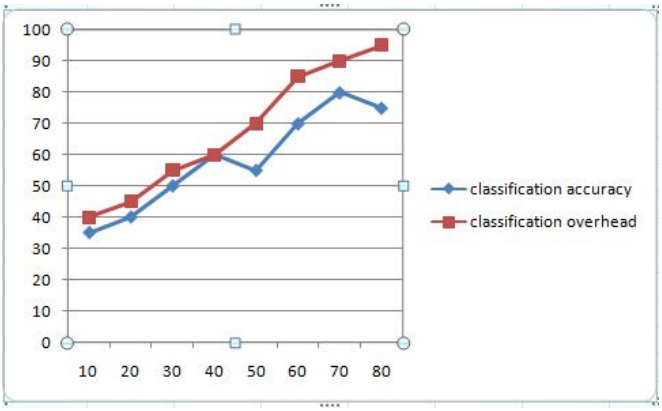

Figure 5: Graph showing accuracy and overhead in percentage

Figure 4 shows the overall energy usage and throughput of the system with a time period of 5 minutes in the x-axis and percentage of its utilization in the y-axis. We can see that as time increases energy usage decreases as well as the throughput will increases. Figure 5 shows the graph of overhead and accuracy of the system with Machine Learning in percentage. As the amount of data trained gets increased, its accuracy and overhead also gets increased.

5. CONCLUSION

IOT enabled aquaponics system could improve its real time monitoring due to live capturing of data through sensors. The water level, pH, temperature content are immediately stabilized through fuzzy based decision making system where human expert knowledge is incorporated in the decision making algorithm. The huge data collected through a long time monitoring is used for prediction through application of svm based in improved overall system performance for a long period of time. The measured parameters like energy consumption and throughput (fig 4) shows that system posses improved load balancing. The measurement of classification accuracy and classification overhead is an evidence for improved system prediction and it ultimately yields a secure aquaponics system.

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