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PREDICTION OF PLANT GROWTH BASED ON SMART AQUAPONICS SYSTEM

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Abstract— The monitoring of aquaculture and hydroculture with the aid of sensors is what a smart aquaponics system is all about. Through the use of aquaponics, fish farming can be combined with aquatic-based, terrestrial plant farming, which could also be better defined through its prediction of the sharing of nutrients resource. In an aquaponics system, it is extremely important to properly maintain the temperature of the water as well as the pH value of the water in order to ensure healthy growth of the fish and plants. The objective of this paper is to devise a method for monitoring the temperature of the water as well as the pH level of the water in an aquaponic system. It also adds the controlling system that will be used to maintain a stable environment for the aquaponics system. Using machine learning, a smart aquaponics system illustrates the disparity between the rates at which plants grow in various mediums. It forecasts the development of the aquaponics systems by analyzing parameters such as the amount of ammonia in the water, the temperature of the water, the iron content of the water, etc... In the process of controlling systems, Arduino devices serve both as data collectors and as executers. This paper depicts about an efficient system which minimizes the wastage of water and increases the yields.

Keywords— Aquaculture, Hydroponic, Aquaponics, Machine learning, Arduino, Sensors

I. INTRODUCTION

The practices of aquaculture (the rearing of aquatic animals such as fish) and hydroponics (the cultivation of plants in water) are combined under the umbrella term known as aquaponics. In a system like this, plants and animals coexist in a mutually beneficial relationship, in which they provide sustenance to one another while also eliminating contaminants that could be damaging to the other. Bacteria, in their most fundamental form, decompose the poisons that are produced by fish and provide plant life with sustenance in the form of nitrogen compounds. Bacteria can also be found in soil. The plants will subsequently remove the nitrogen from the water and establish a habitat that is advantageous to the fish. It is a bio integrated food system that enables the production of both plants and animals for consumption, but does not necessitate the use of arable land.

The aquaponic system will subsequently initiate its cycling process at this point. Nitrogen and hydrogen can combine to generate the molecule known as ammonia, which has the chemical formula NH3. Ammonia can be produced by fish in the form of waste and urine, however gill respiration is the primary source. Through a process known as cycling, ammonia is converted into a form of nitrogen known as nitrate that is much easier for plants to assimilate. Nitrosomonas are the first of the two varieties of nitrifying organisms that will colonize the surface of a system. They are drawn to ammonia because it contains nitrogen. Nitrosomonas bacteria are responsible for the transformation of ammonia into nitrites (NO2). Nitrospira is a kind of bacteria that is drawn to nitrites. Nitrospira is responsible for the conversion of the nitrites to the nitrates. Nitrates are typically considered to be safe for fish to consume, while also serving as a vital nutrient for plants.

The amount of information that must be analyzed and manipulated in order to achieve optimal results is one of the challenges that are presented by an aquaponics system. After this, the multiple environmental parameters such as air temperature, water temperature, humidity, pH, light intensity, and so on, as well as other variables such as water level, water flow, and so on, all need to be monitored, and any change in any of these variables requires a change in the environment. This turns into a tremendous undertaking, which is pretty impossible for any individual to manage twenty-four hours a day, seven days a week. The scale and complexity of the aquaculture system, on the other hand, both enhance the likelihood that a mistake will be made by a person. Because of the complexity of the system, it's possible that people won't even be able to notice correlations between events that are happening in seemingly unconnected parts of the structure. As a consequence of this, it is of the utmost importance to develop an intelligent monitoring and control system, particularly for persons who frequently travel. As a result of the rapid growth of technologies such as sensors, the internet, communication, and computers, living a smart lifestyle will become an increasingly common trend in our lives in the future.

Aquaponics systems built on the Internet of Things enable remote monitoring and regulation of water quality. Specific sensor nodes are used to measure the various parameters. The ability to analyze such vast amounts of data is allowing for precise planting, visual management, and well-considered decisions in agricultural output.

II. LITERATURE SURVEY

With the use of IoT, [1]'s aquaponic system is cared after. Data collection and control system execution are split across two Arduino boards. In the meantime, the Raspberry Pi serves as a gateway and web server so that everything can be accessed over the web. The outcome ensures optimal conditions for plant and aquatic life growth by keeping an eye on critical water parameters like pH and temperature.

The embedded system is designed to maintain aquaponic garden in [2]. It is used to control nutrient content on hydroponics. The Forward chaining approach was used to embed machines with intelligence that could detect what parameters the plants need.

Artificial neural networks and Nearest neighbour model techniques has been used to gather the data such as Temperature, Humidity, dissolved oxygen, pH , nitrogen and water content in [3]. Each method employs the user's estimation of the moment and time as a form of aquaponics training information. It is also used as the training data for future decisions to maintain the garden.

Aquaponic system is maintained with the help of Internet of Things in [4]. Parameters such as water temperature and pH is measured. If it drops into an unsafe zone, an alarm will sound to notify the user and a system will kick into gear to fix the issue by switching on the water heating system and the motor at the same time. The information is stored in the database and recovery is recorded for future use.

The monitoring of water temperature, lumens, pH, and air temperature at a frequency of 25 seconds is a requirement specified in reference [5].The system is required to regulate the lighting, heating, and alarm functions and provide a response time of no more than one minute. Additionally, it has the capability to be monitored through a Graphical User Interface (GUI). The MATLAB software will be utilized to simulate and evaluate the system, employing a signal generator for this purpose.

Internet of Things is used to maintain the aquaponic garden in [6]. Many layer architecture of IoT is used such as perception layer. It has been used to convert signals to data. Then Quality of service is been measured for each parameters in aquaponic garden.

The maintenance of aquaponics involves the regulation of pH and temperature within the water, which serves as the primary medium for cultivation, as outlined in reference [7]. The two modules that are implicated in this context are data acquisition and control equipment. The data acquisition module pertains to the methodology of gathering real-time environmental data, such as pH and temperature. The monitoring and control equipment serves as the central hub for the system's operation and executive management.

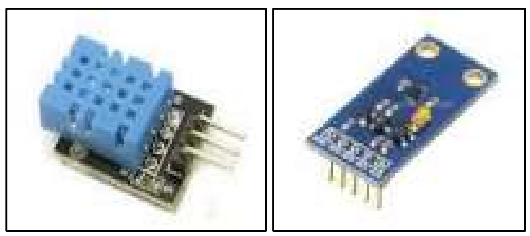
III. PROPOSED SYSTEM

A. Aquaponic Setup

The following has been considered for our work, and the Fig. 1 represents the initial hardware setup for aquaponics system. A perfect location has been chosen to make the initial fish tank and grow bed setup. It is recommended to perform a comprehensive cleaning of the gravel and subsequently position it at the base of the aquarium. This is due to the fact that the gravel acts as a habitat for the nitrifying bacteria, which facilitate the conversion of ammonia into nitrates that can be utilized by the plants. Create a drainage system by drilling holes in the base of your grow bed. Put the water pumps inside the fish tank, and then position the growing tray on topping of the tank so that it is above the tank. The growing environment should be layered into the grow bed. Put some water in the tank for the fish. Turn on the pump and ensure that it is pumping water into the growing medium by ensuring that it is turned on. Place the fish in the aquarium, keeping in mind that you should not have more than half an inch of fish for every gallon of water when you first start stocking the tank. A small number of additional plants or seeds can dramatically boost plant density within a month.

Fig.1. Initial Setup

B. **Prototype Design**



(a) DHT11 (b) BH1750

(c) HC-SR04

Fig.2. Hardware components of proposed system

Aquaponics Temperature Sensor (DHT11) DHT11 will sense temperature and humidity and is been commonly are highlighted in Fig. 2a. NTC (negative temperature coefficient) methodology is been used to measure temperature which uses 8-bit microcontroller to send serial data output of temperature and humidity using GPIO port. DHT11 uses a negative temperature coefficient thermistor, which causes a decrease in its resistance value with an increase in temperature. To get larger resistance value even for the smallest change in temperature, this sensor is calibrated by the manufacturer and made up of semiconductor ceramics or polymers. It is easy to inference with other microcontrollers are VCC, DATA, GND Pins with operating voltage is from 3.5V to 5.5V, Operating current is about 0.3mA and temperature range is from 0 C to 50 C and accuracy is about ±1 C and ±1 %.

Light Sensor (BH1750) BH1750 is a light intensity sensor that measures the intensity according to the amount of light hitting on it. This sensor uses i2C communication protocol which communicates using SCL and SDA pins making it easier to use with microcontrollers. This sensor measure intensity of any light source which not sensitive to IR radiation. The light intensity measure is obtained in the value of Lux through the i2c bus. The analog to digital converter IC converts the analog illuminance to the digital lux value which can be easily interfaced with any edge device. This sensor is shown in Fig. 2b.

Ultrasonic Sensor HC-SR04 The popular ultrasonic sensor used to measure the distance is HC-SR04. In the paper work. HC-SR04 is used for water level depth. HC-SR04 circuitry inbuilt on the module will calculate the time taken for the ultrasonic wave to come back after reflection and turns on the echo pin high for that particular amount of time, this rebound time is used to calculate the distance. This sensor is depicted in Fig. 2c.

The components that has been used in our aquaponic system are represented in Fig. 2. There are few issues in traditional setup such as;

(1) Allowing the Tank water to get too hot.
(2) Not frequently testing Ammonia.
(3) Iron deficiencies in plants.
(4) Water levels of plants in different medium. In order to overcome these issues, few sensors are used. In order to quantify the level of hydrogen-ion activity in aqueous media pH sensor are employed. With the help of water level sensor we can detect the level of substances that can flow. The Ultrasonic rangefinder takes the time it takes for the sound to return after being reflected off an object is used to calculate its distance.

These sensors are connected to the Arduino board. Arduino Uno is an open source microcontroller board supported the microchip. pH and water level sensors are placed in aquatic setup to gather the dataset. Three Ultrasonic distance sensors are used to measure the growth of same plant in three different medium. These ultrasonic sensors are placed above the plants to measure the distance between the plant and the sensor with the help of sound waves. The data from each sensors are collected and stored in the database as table set.

C. Processor Control Unit

The project uses the embedded processor ATMega328p as the main controller toprocess all the sensor data parameters and drive the actuator, which includes the LED indicator and water pump system. In order to digitize the required parameter value to the precise unit value, the Arduino IDE has utilized that programming with the C program to read the value of the data of the analog sensors via the ADC at specified time intervals. In order to communicate the processed data to the selected dashboard platform and display the necessary measured sensor data parameter, the controller is additionally integrated with the GSM Module of the controller.

All water parameter data is wirelessly synchronized throughout each appropriate setup period for the owner's system to assess the gardening system.

D. System Architecture

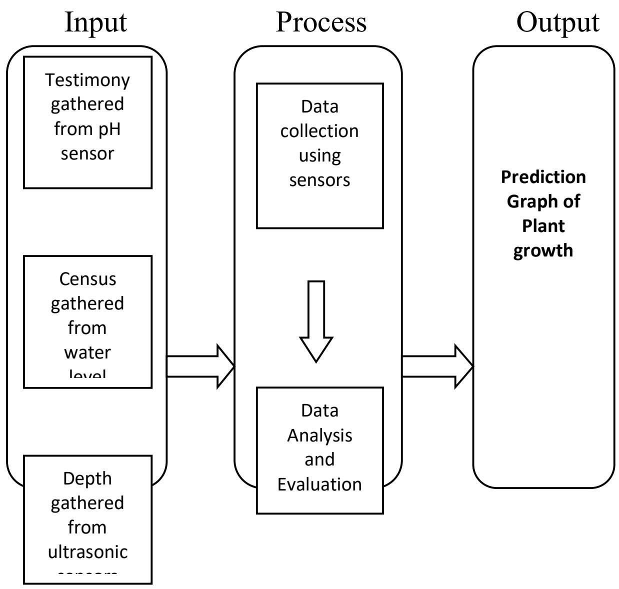


Fig.3. The IPO model of the proposed system for aquaponics

The Fig. 3 depicts the Input-Processing-Output (IPO) paradigm of the suggested aquaponics system. Each cycle brings a new batch of data, which typically consists of the following: (1) Sensor data in numerical form. 2. Distance from plants to sensors.

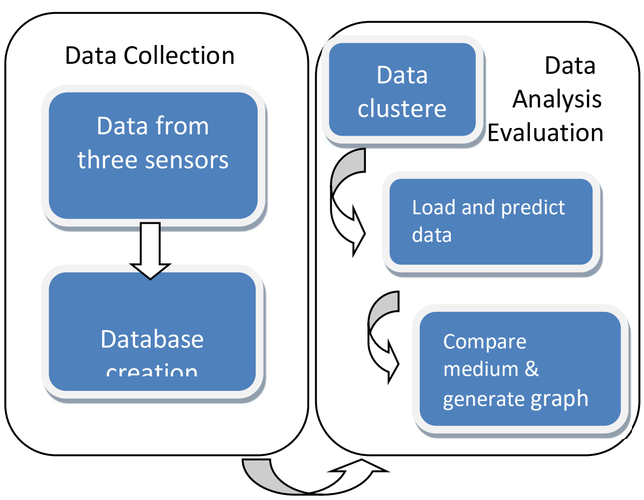


Fig.4.Multimodal processing system of the proposed work

The system outputs the prediction graph that selects the best grow bed of the particular plant. The "processing" part of the system consists of two modules, namely the Data Collection using sensors and Data Analysis and Evaluation. The aforementioned modules interact with one another using an architecture known as client server, as seen in Figure 4.The next subsections will provide further explanation of these modules.

E. Sensor Feature Extraction

Triggering of an event is conducted on the edge device, which is having low computation power. The following events are triggered automatically such as automatic switching on/off of UV light, automatic turning of water pump to pump the water, automatic switching of fan to cool the greenhouse. In this paper, all the sensor parameters such as Temperature, water depth and water PH value were used as features and reading from each features for 10 different interval time of a day for 15 days was collected as training features. These features were used to train a machine-learning algorithm that aids in the automatic aquaponics control system.

F. Water pH Detection

The main objective of smart aquaponics is to maintain the equilibrium in water pH levels for a longer duration. As the water in aqua pond gets contaminated very quickly, if not monitored might hamper the growth of fish also lead to death. The ideal pH level for fish is in the range of 7-8 as fish blood has a pH of 7.4. Most of the fishes can adapt to the pH level of their environment from 6.0 to 9.0 as long as there no dramatic fluctuations. In this paper, Atlas scientific digital pH value reader [12] is being used, and get water pH values. The pH reading is taken as one of the features.

IV. EXPERIMENTAL SETUP AND RESULTS

A. Data Collection using sensors

Sensor data refers to the information generated by a device that is designed to detect and react to a specific type of input from the surrounding physical environment. The resultant data can serve as a means to furnish insights or serve as an input to a different system or to direct the course of action. In our setup the sensors such as pH sensor and water level detector is placed in aquarium where the ammonia content is measured. Ultrasonic sensors are placed above the plants which are used to measure the distance between plants and the sensor. These sensors uses SONAR to determine the distance of the object just like the bat do.

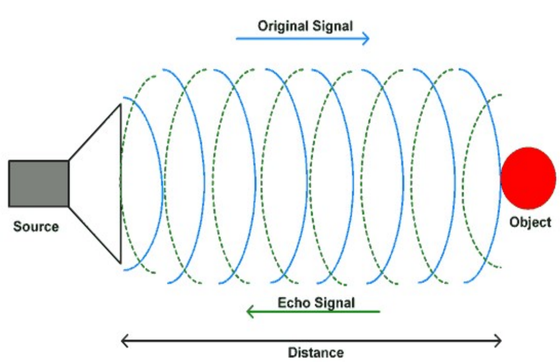


Fig.5. Working of ultrasonic sensor

The exact working of ultrasonic sensor are represented in Fig.5, and Fig.6 depicts the bar graph which depicts the exact difference between smartly grown plant and traditionally grown plant. As the sensor is placed above the plant. If the distance between the plant and the sensor reduces then there is a constant growth in the plant. Then the pH values and water level values are stored in the database. Similarly distance which has been collected by the ultrasonic sensor is also stored in the database. This acts as the input to the succeeding module.

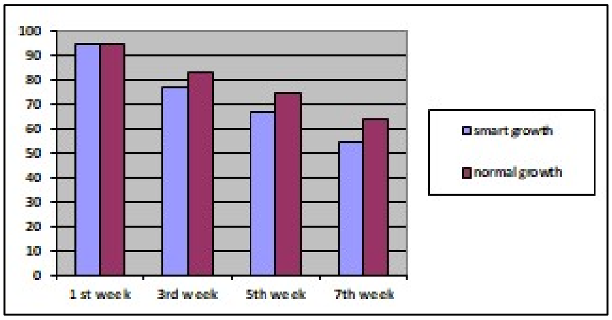


Fig.6 Variations in Growth

B. Data Analysis and Evaluation

When data are collected from sensors (i.e.., pH data, water level and growth parameter, the proposed system creates a database in order to display the gathered data. Then an algorithm is applied to the data which has been collected in the database. Artificial Neural Networks is the algorithm that has been applied within the planned system for knowledge analysis part. Artificial Neural Networks are the procedure modes that are inspired by the human brainA biological model served as the basis for the creation of an artificial neural network with neurons programmed to carry out certain functions. A neural network primarily acquires information through learning. The information that has been learned is hold on with the junction weights. It's merely viewed within the sort of directed graph during which ANN (Artificial Neural Network) has artificial neurons known as nodes and directed edges with weights. They kind a association between neuron input and neuron output. It receives information from the outer world so as to realize information the data that has been gathered from the external world area unit are summed up within the computing unit. After that, the activation function is prepared to be passed on to the transfer function so that the output can be obtained. Hyperbolic tangent function and Sigmoid function has been used as a activation functions in aquaponic setup. Sigmoid function is an activation function in terms of underlying gate structure to correlate neurons. It distinguishes perceptron from sigmoid neurons. It's needed in neural networks that the output changes terribly slowly with input. In neural systems, the function known as the hyperbolic tangent can be used instead of the sigmoidal function in some situations. Tangent It's possible that the hyperbolic function takes a straightforward form, similar to the sigmoid function. Derivatives of tangent function is,

Output $y = \tanh(x)$

The tangent function is,

$$\mathrm{Tanh}(x) = (e^{x} - e^{-x}) / (e^{x} + e^{-x})$$

This function produces output in scales of [-1 , +1]. In the following ways, ANN has been used in the proposed system.

[1] The data that has been gathered by the sensors are hold within the database.

[2] The information has been flaunted to via XSL sheet.

[3] The standard knowledge which has been hold on within the information is additionally displayed within the XSL sheet in order that the user is able to compare it with gathered knowledge.

[4] Then Artificial Neural Network algorithm has been applied so as to coach the smart aquaponic system.

[5] Whereas applying algorithm Activation functions is loaded within the system.

[6] The activation functions like binary, sigmoidal hyperbolic and tan hyperbolic sigmoidal function is been used.

[7] Binary activation function is however the output values are going to be 0 or 1. The Sigmoidal Hyperbolic behave exhibits a characteristic S-shaped curve. The Tan Hyperbolic functioning is utilized as an approximation for the net input.

[8] Using these activation functions the Smart Aquaponic system begins the analysis phase.

[9] In the analysis phase, all the five parameters has been evaluated and converted into single value. That value is named as analysed data.

C. Sensor Performance Measure

The sensor used in building the system is calibrated by the manufacture. In this research work, we carry out around 15 different condition sensor sanity check before deploying the sensor to the aquaponics system to avoid false positives. The sensors reading like temperature, humidity, a light intensity value, and water depth are being cross verified with actual reading using advance measuring instruments like the digital thermometer, laser depth analyzer, and light intensity meter. The actual and observed data with error rate for temperature, humidity, light intensity, and water depth measure are demonstrated in Table 1 and shown in Fig. 7 were sensor performance measure compared average actual reading represented in blue and average observed is represented in orange.

Table 1. Performance of Sensors Actual Vs Observed Data

Sensor	**Average of Actual Data**	**Average of Observed Data**	**Error**
DHT11	22.4	22.8	0.5
BH1750	85.7	86.2	0.6
HC-SR04	7.1	7.4	0.4

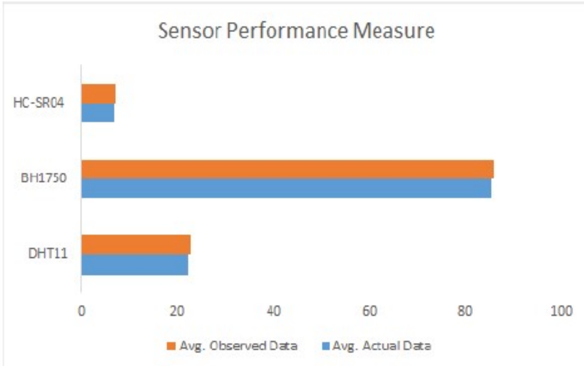


Fig. 7 Performance Measure of Sensors

V Conclusion and Future Work

This study proposes a novel aquaponic system that utilizes the Internet of Things (IoT) and Neural Networks (NN) to enhance its intelligence. The text discusses a compact and intelligent Aquaponics system that operates with minimal human intervention, yet yields a significant harvest of fish and vegetables through the use of a single nutrient source, namely fish feed. Aquaponics offers several benefits such as enhanced water use efficiency, improved nutrient utilization, superior product quality, and increased food security. Additionally, it is possible to remotely monitor various environmental parameters such as water temperature, pH levels, and humidity through an online platform. In summary, the aquaponic setup is an effective system that reduces water waste and enhances crop productivity. For future work, ANN has been used to train the data in the smart aquaponic setup and a GUI has been developed for generating the graph in both user traditional data and Smart aquaponic data.

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