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Smart Automation of Precision Fish Farming Using Internet Of Things (IoT)

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ABSTRACT: Agriculture was a major exchange earns before the discovery of crude oil. In the western part of the country cocoa was a major crop produced and exported, in the northern part, it is groundnut with several pyramids of groundnuts bag on display while in the eastern part of the country, we had palm oil and kernel. In recent time due to fall in the price of crude oil in the international market, which had negatively affected the country's economy, the country is looking at diversifying its economy from a sole crude oil based one to a multidimensional based one. Smart automation of precision farming makes farming less tedious with greater results. The purpose of the research in this paper is to give a review of previous works on smart automation, discuss some of the factors responsible for optimum growth of fish farming and the architecture of the power logging unit. With the knowledge imparted by this paper, the set up a smart automation for fish farming can be easily achieved.

KEYWORDS: Agriculture, precision farming, internet of things, technology, sensors.

1 INTRODUCTION

Nigeria is a country with a population of 198 million people [1] and a total area of 923,800 sq. km. It occupies about 14 per cent of land area in West Africa and lies between 4°N and 14°N, and between 3°E and 15°E. It is located within the tropics and thus experiences high temperatures throughout the year with a mean temperature of 27°C. The average maximum temperatures vary from 32°C along the coast to 41°C in the far north, while mean minimum figures range from 21°C in the coast to under 13°C in the north. The climate of the country varies from a very wet coastal area with annual rainfall greater than 3,500 mm to the Sahel region in the north western and north eastern parts, with annual rain fall less than 600 mm.

In the past, agriculture was a major exchange earns before the discovery of crude oil. In the western part of the country cocoa was a major crop produced and exported, in the northern part, it is groundnut with several pyramids of groundnuts bag on display while in the eastern part of the country, we had palm oil and kernel. In recent time due to fall in the price of crude oil in the international market, which had negatively affected the country's economy, the country is looking at diversifying its economy from a sole crude oil based one to a multidimensional based one. Agricultural sector remains a viable option in this diversification. It remains the single largest contributor to the well-being of the rural poor with a contribution of over 40% of the Gross Domestic Product (GDP) and it employment of about 60% of the working population [2]. Thus, for agriculture to remain a viable option, there is a need to improve the productivity of cultivated crop. This means the ratio of the crop harvested in a cultivated area to inputs used in the crop cultivation should be high. Maximizing inputs such as labor, land, fertilization, irrigation and so on will reduce cost, and ultimately improve yields.

Technology is considered a key tool to improving crop productivity through the measuring and reporting of factors responsible for the growth of crop to provide information on how, when and where to use farming inputs during farming cultivation in such a way to reduce wastage, provide all necessary requirements for the crop and enhance yield. Information on the day-to-day factors influencing crop growth has been important for farmers for ages and in the past, farmers had mainly used direct human observations to recognize these factors. However, with technology, automatic sensor systems such as soil moisture sensors, weather stations and satellite or airborne sensors have been adopted [3]. Sensors and sensor networks enable local and real-time observations and monitoring, and may foster more sustainable crop production practices and, thus, lower negative environmental impacts of agriculture and food safety risks ([4] . Use of information technologies in the regional agricultural infrastructure is of great importance and recent trends in agricultural production are based on these technologies.

The concept called precision agriculture is a form of a measuring system that provides information about the physical value of some variable being measured [5] . It is made up of primary sensor, variable conversion, signal processing transmission and actuation elements and have found wide application in many areas of human life ranging from military[6], health[7], transport and logistics [8] environment [9] agriculture [10]and so on. Precision farming takes into account local variations of the crop and accordingly adjust all agro-technical measures, thus providing more efficient and healthier agricultural production with considerable savings. Wireless Sensor Network (WSN) and Remote Sensing are of special interest in precision agriculture, since they provide timely access to in-field data and prompt reactions. Consequently, agro-technical measures can be administrated more precisely thus leading to a higher level of food quality, environmental protection and significant savings. Another benefit is better understanding of the underlying processes in agriculture and validation and improvement of the applied models. WSN are composed of multiple sensors which communicate through wireless connections and acquire data of interest.

In terms of precision agriculture, sensors acquire data such as: humidity, soil temperature, illumination, plant diameter growth rate, etc, within a longer time interval. Large number of sensors distributed appropriately allow for timely and precise crop monitoring, and wireless communication enables the deployment of sensor networks on practically all terrains. Remote sensing is based on the usage of low-cost unmanned aerial vehicles, capable of acquiring important data, otherwise inacceptable from the ground. Images gathered in this way provide simple identification of crop condition, by assessing the bio-mass or by detecting parts of the field with nutrition deficiency.

El-Kader and El-Basoni in [11] defined precision farming (PF) as the ability to handle variations in productivity within a field and maximize financial return by reducing waste and minimize impact of the environment using automated data collection, documentation and utilization of such information for strategic farm management decisions through sensing and communication technology. The study further sensor nodes deployed in an environment, as shown in Figure 1, to measure environmental parameters like temperature, pressure, humidity, or location of objects. Signals from sensor nodes are transmitted to a local sink which may be connected to a gateway in order to send the data to an external network such as internet so that a remote user can access information about the environment. The data thus received from sensor nodes may be analyzed and appropriate decision or action taken depending on the application itself. In precision farming, information received about the farm helps the farmer in using the right input needed to improve the crop yield such as fertilizer, water, etc., on the farm. Precise application of these inputs, at the right time, in the right place and in the right amount will greatly reduce cost and also improve productivity.

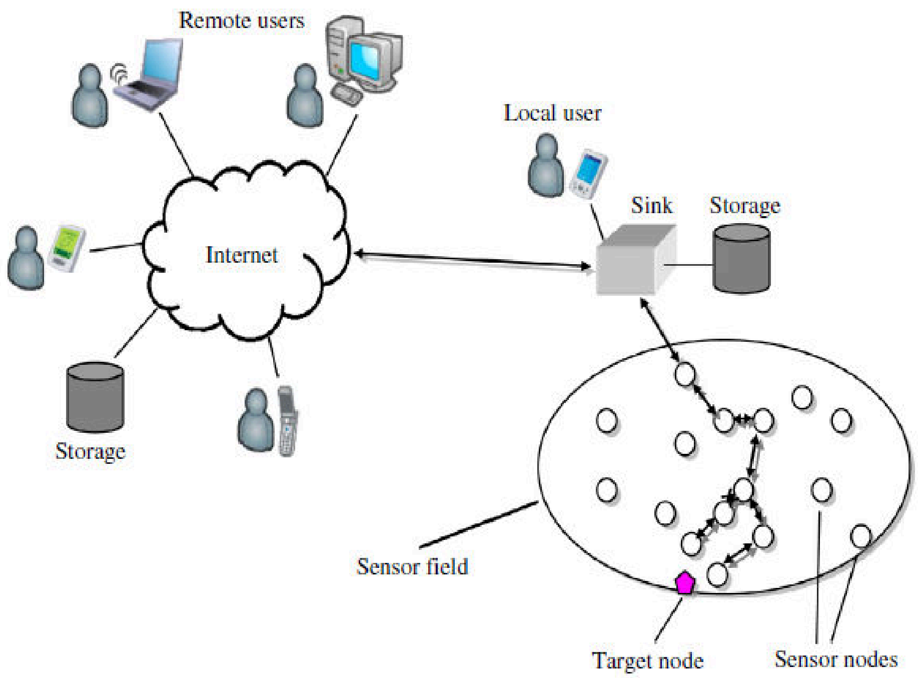

Fig. 1. A Typical Wireless Sensor Network

2 LITERATURE REVIEW

In this section, the state of art of the systems for fish farm monitoring is shown. Several authors propose different systems for water quality monitoring.

Water quality monitoring and fish behavior monitoring are crucial to improve the efficiency of aquiculture. In this section, the related work on the available water quality monitoring systems and some of the research performed on fish behavior monitoring is presented. Wireless Sensor Networks (WSN) have become a solution for performing water quality monitoring.

[12] designed a monitoring an experimental aquaculture recirculating system using ZigBee wireless sensor network to monitoring Temperature, dissolved oxygen, water and air pressure as well as electric current sensors. Modules for reading and transmitting sensor values through a ZigBee wireless network were developed and tested. The modules were installed in an aquaculture recirculating system to transmit sensor values to the network coordinator. A monitoring program was created in order to display and store sensor values and to compare them with reference limits. An alert is emitted in case reference limits have been reached. E-mail and an SMS message alert can also be sent to the cellular phone of the system administrator, so immediate action can be taken. A web interface allows internet access to the sensor values. The present work demonstrates the applicability of ZigBee wireless sensor network technology to aquaculture recirculating systems.

[13] designed and presented a wireless sensor network monitoring and control system for aquaculture. The system can detect and control water quality parameters of temperature, dissolved oxygen content, pH value, and water level in real-time. The sensor nodes collect the water quality parameters and transmit them to the base station host computer through ZigBee wireless communication standard. The host computer is used for data analysis, processing and presentation using LabVIEW software platform. The water quality parameters will be sent to owners through short messages from the base station via the Global System for Mobile (GSM) module for notification. The experimental evaluation of the network performance metrics of quality of communication link, battery performance and data aggregation was presented. The experimental results show that the system has great prospect and can be used to operate in real world environment for optimum control of aquaculture environment.

In [14] a prototype and proof of concept of a distributed monitoring system of the most important variables in aquaculture water quality was presented. The proposed system monitors the water quality based on wireless sensor networks and on the Internet of Things (IoT). The information obtained was useful to know determine the status of the aquaculture environment and to optimize resources for the care of the pond.

[15] study was focused on the implementation of an efficient underwater acoustic network suitable for long lasting environmental monitoring in fish farming. A SUNSET Software Defined Communication Stack (SDCS) was used to provide networking capabilities to underwater nodes communicating acoustically through AppliCon SeaModem modems. The Hydrolab Series 5 probes were used to monitor the water quality. Lifetime of underwater nodes was extended through the use of a novel device that allows to harvest energy from underwater water currents via suitable propellers. Also, novel sleep and wake up mechanisms were designed and implemented into the underwater nodes to minimize the energy consumption of the system during the idle periods. The performance of the proposed system was evaluated in field by monitoring the water quality in three fish farming cages located in the Mediterranean Sea, Italy.

[16] monitored aquaculture water quality by measuring various water parameters using wireless sensor network in real-time in order to improve the quality of aquaculture products. The system uses solar cells and lithium cells for power supply. A YCS-2000 dissolved oxygen sensor, pH electrode, Pt1000 temperature sensor and ammonia nitrogen sensor were used to monitor the parameters of aquaculture water quality; STM32F103 chip was used for data processing; Zigbee and GPRS modules were used for data transmission to the remote monitoring center, where the data were stored and displayed. The system was connected with aerator to realize automatic control of dissolved oxygen concentration. The test results showed high confidence level of data transmission with a packet loss rate of 0.43%.

A review by [17] identify the use of optical sensors and machine vision system to provide the possibility of developing faster, cheaper and noninvasive methods for *in situ* and after harvesting monitoring of quality in aquaculture. This review describes the most recent technologies and the suitability of different optical sensors for the fish farming management and also assessment, measurement and prediction of fish products quality. Two major areas of optical sensors applications in aquaculture were discussed in the review: pre-harvesting and during cultivation and post-harvesting. Finally, accuracy and uncertainty of optical sensors applications in aquaculture were also discussed.

Study by [18] shows a set of sensors for monitoring the water quality and fish behavior in aquaculture tanks during the feeding process. The WSN is based on physical sensors, composed of simple electronic components. The system proposed was able to monitor water quality parameters, tank status, the feed falling and fish swimming depth and velocity. In addition, the system includes smart algorithm to reduce the energy waste when sending the information from the node to the database. The system is composed of three nodes in each tank that send the information though the local area network to a database on the Internet and a smart algorithm that detects abnormal values and sends alarms when they happen. The study further looked at the cost of this development. The total cost of the sensors and nodes for the proposed system was less than 90 €.

The systems for water quality monitoring measure the same parameters not considering other important factors to monitor such as the turbidity of the water. Moreover, many of the papers do not specify which sensors they have utilized, or they employ expensive sensors, resulting in a high-cost system that is difficult to implement in fish farms with few resources. Furthermore, fish behavior monitoring is not usually incorporated in the same system increasing the investment owners must do to improve the efficiency of their fish farm. In this paper, we present a low-cost water quality and fish behavior monitoring system. The system can measure the water quality parameters, tank state factors and fish behavior during the feeding process.

3 Factors Affecting Optimum Growth Of Fish Production

In order to develop an effective smart fish farming system, there is the need to address the factors responsible for the optimum growth of this animal. Fish live, eat and excrete in water. Thus, water quality will be the fulcrum for the optimum growth of fish. Monitoring and controlling the quality of the environment (water) will go a long way of improving the growth. This study investigates several water qualities such as dissolved oxygen, pH, temperature, salinity, turbidity and nitrogen compounds. The description of these parameters will give a depth insight on how these parameters influence each other. Table 1 gives an overview of the water quality parameters with their standard values.

Table 1. Water quality parameters and their standard values

Parameters	**Standard Values**
Dissolved Oxygen	> 4.0mg/L
pH	Species dependent
Salinity	7.5 – 8.5
Carbon dioxide (CO2)	< 10 ppm
Ammonia (NH_4^+/NH_4 -N)	0-0.5 ppm
Nitrite(NO_2^-)	< 1 ppm
Hardness	40-400 ppm
Alkalinity	50-300 ppm
H2S	0 ppm
BOD	< 50 mg/L

Each water quality parameter alone can directly affect the animal's health. Exposure fish to improper levels identified factors can lead to stress, disease and ultimately loss in production. However, in the complex and dynamic environment of aquaculture ponds, water quality parameters also influence each other. Unbalanced levels of temperature and pH can increase the toxicity of ammonia and hydrogen sulfide. Thus, maintaining balanced levels of water quality parameters is fundamental for both the health and growth of culture organisms. It is recommended to monitor and assess water quality parameters on a routine basis.

3.1 DISSOLVED OXYGEN

Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water [19]. It is considered to be one of the most important parameters in aquaculture since fish depend on oxygen for survival. Maintaining good levels of DO in water is essential for successful production. It has a direct influence on feed intake, disease resistance and metabolism. A sub-optimal level is very stressful for fish and shrimp. Study by [20] shows that the dynamic oxygen cycle of ponds fluctuates throughout the day due to phytoplankton photosynthesis and respiration as shown in Fig 2.

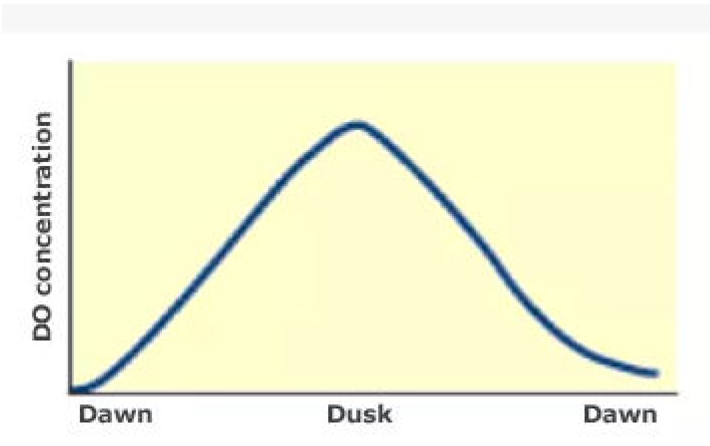

Fig. 2. The Daily Cycle of Oxygen in a Pond

Maximum DO occurs in the late afternoon due to the buildup of O_2 during the day through photosynthesis. As phytoplankton (microscopic algae) usually consumes the most O_2 and since photosynthesis does not occur during the night, DO level declines. Critically low DO occurs in ponds specifically when algal blooms crash. The subsequent bacterial decomposition of the dead algae cells demands a lot of oxygen. Managing the equilibrium of photosynthesis and respiration as well as the algae growth - is an important task in the daily work of a farmer. When feeding the fish and shrimp, oxygen demand is higher due to increased energy expenditure (also known as specific dynamic action).

3.2 TEMPERATURE

Temperature is another important water quality parameter. It can affect fish and shrimp metabolism, feeding rates and the degree of ammonia toxicity. Temperature also has a direct impact on biota respiration (O_2 consumption) rates and influences the solubility of O_2 (warmer water holds less O_2 than cooler water). Although aquatic animals modify their body temperature to the environment and are sensitive to rapid temperature variations, temperature can be controlled in ponds by pumping in fresh water to stabilize the temperature. For each species, there is a range of temperature conditions, it is therefore important to adapt fish and shrimp progressively when transferring them from tank to pond. Also, the O_2 cycle and thus, the DO levels can be affected by changes in the environment; a cloudy day will diminish the photosynthetic O_2 input to DO. Correspondingly, uncommonly high temperatures will decrease the solubility of O_2 in water and hence lower DO. When a pond is in equilibrium DO will not change drastically.

3.3 CARBON DIOXIDE (CO_2)

Carbon dioxide (CO_2) in ponds is primarily produced through respiration by fish/shrimp and the microscopic plants and animals that constitute the pond biota. Carbon dioxide levels (and toxicity) are highest when DO levels are lowest (Fig 2). Thus, dawn is a critical time for monitoring DO and CO_2. High CO_2 concentrations inhibit the ability of fish and shrimp to extract O_2 from the water, reducing the tolerance to low O_2 conditions and inducing stress comparable to suffocation. An increase in CO_2 may also decrease the pH, which can lead to toxicity of nitrite. If plants in the water absorb too much CO_2 for photosynthesis during the day, the pH will increase, and the fish and shrimp are subjected to higher un-ionized toxic ammonia (NH_3) concentrations. Carbon dioxide concentrations above 60 ppm may be lethal. In an emergency, CO_2 can be removed by adding liming agents such as quicklime, hydrated lime or sodium carbonate to the pond water.

3.4 PH

pH is a measure of acidity (hydrogen ions) or alkalinity of the water. It is important to maintain a stable pH at a safe range because it affects the metabolism and other physiological processes of culture organisms. It can create stress, enhance the susceptibility to disease, lower the production levels and cause poor growth and even death. Signs of sub-optimal pH are besides others increased mucus on the gill surfaces of fish, unusual swimming behavior, fin fray, harm to the eye lens as well as poor phytoplankton and zooplankton growth. Optimal pH levels in the pond should be in the range of 7.5 to 8.5. The CO_2 concentration in the water also influences the pH, e. g. an increase in CO_2 decreases the pH. As phytoplankton in the water utilizes CO_2 for photosynthesis, the pH will vary naturally throughout daylight hours. pH is generally lowest at sunrise (due to respiration and release of CO_2 during the night) and highest in the afternoon when algae utilization of CO_2 is at its greatest. Waters of moderate alkalinity are more buffered and there is a lesser degree of pH variation.

3.5 SENSORS AND ACTUATORS

DS18B20 is a temperature sensor consisting of a waterproof probe and long wire shape, which is suitable for sensing temperature of water in an enclosed area. The sensor provides 9 to 12-bit temperature readings over a 1-Wire interface, so that only one wire needs to be connected from a central microprocessor aside the positive power and ground as shown in Fig 3.

Fig. 3. DS18B20 temperature sensor

The sensor has an operating temperature range of -55°C to +125°C and is accurate to ±0.5°C over the range of -10°C to +85°C. In addition, the DS18B20 can derive power directly from the data line, eliminating the need for an external power supply.

A pH meter relies on a voltage test to determine hydrogen ion levels and thus pH. The more hydrogen ions in a solution, the more conductive it will be. So the more acidic a solution, the more electricity it will conduct. A pH sensor circuit is completed when the sample comes in contact with two electrodes, a glass electrode and a reference electrode, which are found on the sensor probe. The electrons travelling around the circuit are attracted to the electrodes' membrane. The glass electrode has a permeable membrane made from specialized glass, which houses a chemical solution and a silver-based wire. The reference electrode is also made up of a wire in a chemical solution. The reference electrode is stable and works as a buffer and a reference against which the other electrode can be compared, and the pH determined. The glass electrode attracts the hydrogen ions. This then creates a small voltage which can be compared to the reference electrode. The voltage difference between the two electrodes is then sent as a signal to the indicator, which is translated into a pH reading. A pH <5.0 indicates the soil is strongly acidic, a pH of 5.5 moderately acidic, 6.0 indicates slightly acidic, 6.5 to 7.5 is neutral, 7.5 to 8.5 is moderately alkaline and >8.5 is strongly alkaline. Fig 4 shows the pH sensor with probe.

Fig. 4. pH sensor with probe

Turbidity is the quantitative measure of suspended particles in a fluid. Turbidity Sensor is the device used in measuring turbidity in liquids. It uses light to convey information about turbidity in water. Water flows between the two projections of the transparent plastic can as shown in Fig 5. These projections house the photo transistor and the photodiode respectively. The phototransistor emits light rays that are supposed to reach the photodiode. These light rays come across the water flow and lose their path when they meet any suspended particle in the water. As a result, the light received at the photodiode is less in amplitude when compared to that when it was emitted. This difference in amount of light sent and received is conveyed to the micro controller operating the sensor and decisions are taken in accordance to that. For instance, in case of more turbid water, a dishwasher will increase water cycles and would less recycle the water.

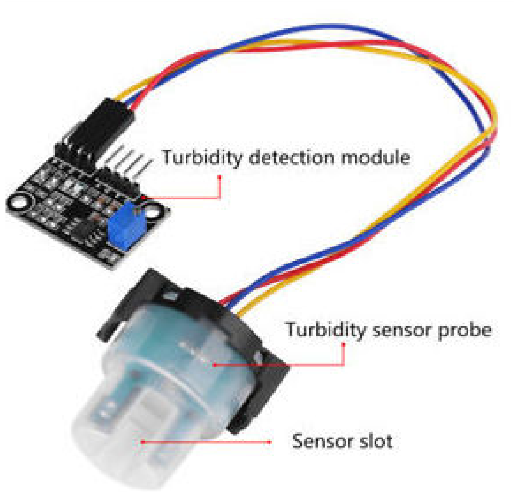

Fig. 5. Turbidity Sensor

The base station (BS) receives sensor readings sent from the sensor fields. This is a data logger which does not require a host to operate. It can be installed in almost any location, and left to operate unattended. With internet and the help of application programming interface, scripts written in high level language and running on the PC, sensor data are posted to cloud server in the cloud.

4 Architecture Of The Data Logging Unit

A low power credit-card-sized single-board computer Raspberry Pi Model B was used as the base station. It has a variety of interfacing peripherals, including USB port, HDMI port, 512MB RAM, SD Card storage and interestingly 8 GPIO port for expansion. Monitor, keyboard, and mouse can be connected to Raspberry Pi through HDMI and USB connectors [21]. Raspberry Pi was connected to a local area network through USB Wi-Fi adapter, and was accessed through SSH remote login. A code was developed using python, an open source programming language, to receive sensed data, store the data in comma separated value format (.csv) and post the data to xively.com, a cloud service using application programming interface (API) key and feed id. Xively.com provides API libraries for a wide range of platforms including the Arduino and Python [21]. Several steps were taken to setup xively developer account for the sensed data. The base station was configured to log data to the cloud every 30 minutes making 48 sensed data per sensor node in a day. Fig 6 shows the architecture of the proposed base station.

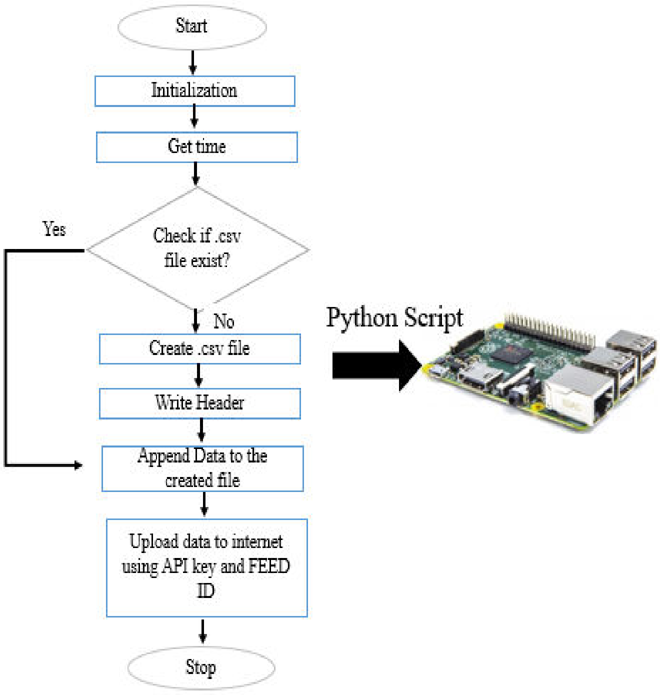

Fig. 6. Architecture of the data logging Unit….

5 Conclusion

Careful monitoring of water quality parameters is important to understand the interactions between parameters and effects on shrimp and fish feeding, their growth and health. Each water parameter alone may not tell much, but several parameters together can reveal dynamic processes taking place in the pond. Water quality records will allow farmers to note changes and make decisions fast so that corrective actions can be taken quickly.

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