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Design and Implementation of Robust Controllers for an Intelligent Incubation Pisciculture System

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Abstract

Aquaculture is major occupation for the humans living at coastal areas. The fresh water cultivation of the certain species is prominent in tropical and sub-tropical climates. Here the proposed work shows the relation-ship between the growth of the certain species of marine habitats and the factors affecting their growth with respect to the medium of their living. Advancement of embedded systems in aquaculture leads to new innovations of monitoring and controlling the various parameters. Here the embedded system based application is used, through which the monitoring and controlling of the light is done with the help of LabVIEW based PI controller as well as Fuzzy controller for the effective and healthy growth of the marine habitat. The Designed controllers are energy efficient based controller for controlling the Light Source (LS) via appropriate lighting control levels. The controlling and managing of the system is based on the present light intensity with the help of virtual controller. The proposed work involves the designing and implementation of PI controller and the fuzzy controller for the real time setup to monitor and control the process for optimal and feasible solution. Also the comparison of both the controllers is done in terms of their efficiency, response time and performance.

Keywords*: PV cell, DAQmx-6211 (Data acquisition card), LabVIEW, LS*

1. Introduction

Now a day's pollution of environment has become common due to various revolutions in the modern world, all of these revolutions can benefit the humans in many ways but this modernization is effecting the global life cycle. One of the lifecycle getting effected by the global revolution is marine life cycle, due to the global warming the rain is effected by the amount of acids in the atmosphere and results in acid rains which directly effects the marine lifecycle due to the change in the pH of the water and also the wastage from the industries directly goes into the ocean bodies which results in contamination of water and effects the life cycle in water, indirectly the mercury levels are getting increased which directly effects the flora and fauna of the marine life, the consumption of the contaminated flora and fauna will lead to health problems in the humans so to overcome these effects Aquaculture has been adopted by lot of people to get more production and healthy food

Fishes are affected by light in many ways. There are several documented studies on spawning in some species being triggered by changes in the day/night cycle, and the hatching of eggs and the growth rate of few can be impacted significantly depending upon the presence and intensity of light. Fish health is connected to the intensity of light, various types of light, and sudden changes in the light i.e., light to dark, dark to light. To understand this, some must know something about the fish's physiology. The basic receptor of light is the eye, but other body cells are also sensitive to light.

In recent years with the increments of species and production, the research and application of aquaculture production and management automation technology has been also got more extensive attention. Now a days there is high demands for the systems which integrates control and automation techniques with low cost, minimal ecological impact, and ease of use.

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2. Liturature Survey

It is a known fact that India is and agricultural country. But India is peninsula, surrounding with water bodies on three sides of it. So the coastal region is also extends to several kilometers, which leads to the aquaculture as their occupation by lot of people. There are two types of aquaculture facilities mainly indoor and outdoor facilities. Here in this paper, the topic concentrates on hatchery and nursery phase and that too more specifically about the indoor hatchery and nursery [1].

Figure 1. In-door Fresh water cultivation

The hatchery and nursery should be located inland where there is ample supply of good freshwater. Saline water required for larval development can be transported and mixed with freshwater to attain the desired salinity. The quality of intake water, whether it is saline or fresh, is of paramount importance for efficient hatchery operation. Water quality is thus a critical factor in site selection. Hatchery sites should preferably be far from cities, harbours and industrial centres, or other activities, which may pollute the water supply. In all cases, water supplies need careful analysis during site selection, to determine their physical, chemical, and biological characteristics, and the extent to which these may vary daily, seasonally, or through other cycles [2]. Special care is needed in hatcheries that are situated in or near areas where the use of pesticides, herbicides, and fertilizers is intensive. Ideally, freshwater should be obtained from underground sources. The water for use in hatcheries should be 12-16 ppt, should have a pH of 7.0 to 8.5, and contain a minimum dissolved oxygen level of 5 ppm. High levels of heavy metals, such as mercury (Hg), lead (Pb) and zinc (Zn), should also be avoided, since these are most likely to be caused by industrial pollution [3].

Temperature is a key factor. Seasonal production is promising in semi-tropical zones where the monthly average air temperature remains above 20°C for at least seven months of the year. The most favourable temperature range for year-round production is between 25°C and 31°C, with the best results achievable if the water temperature is between 28°C and 31°C. The temperature of the rearing water is governed not only by the air and ground temperature but also by solar warming and the cooling effects of wind and evaporation. The rate by which pond water is exchanged and the temperature of the incoming water are also important considerations.

3. Proposed Method

Here the proposed methodology is to measure and control the light levels for the indoor hatcheries and nurseries. The light plays a vital role in plants food production i.e., photosynthesis, the most important life cycle on earth. The light also helps the water bodies to grow the algae and other necessary plankton. These are fed on by the habitat to grow big and healthy. Thus the light also plays a vital role in the aquaculture field for the healthy growth of the habitat, if sufficient amount of light is not provided then the fishes may not get the natural food for their better growth, this is the most common problem in all the indoor nurseries and hatcheries. Here the sufficient amount of light is more necessary as the hatcheries should be kept warm and sufficient amount of light is required for the high breeding requirements. This helps us to increase the larvae production by giving the hatcheries sufficient light and temperature.

The indoor setup for this system basically comprises of large tanks with combination of fresh water and some tap water to maintain its salinity for the growth of algae, some lights to illuminate the tanks for the providing sufficient amount of light and temperature. PV sensors are used to capture the light outside. This PV is interfaced with the system through NI-DAQmx 6211data acquisition module card which supports 16 analog inputs and 2 analog output channels with a voltage ranging between ± 10 volts. The sampling rate of the acquisition card module is 250k samples/second with 16-bit resolution. The graphical program written in LabVIEW is then linked to the setup through the acquisition module. There are various parameters other than light which effects the aquaculture like temperature, dissolved oxygen content, transparency of water etc.

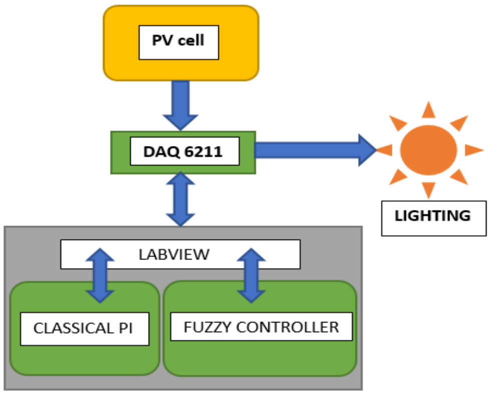

Figure 2. Approach to the problem

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily [2], [5]. The discussion can be made in several sub-chapters.

4. Hardware Description

This part discuss about the overall hardware components involved in the system i.e., Solar Panel, Data acquisition card, photo voltaic cell and PC with LabVIEW.

4.1. Photovolatic Cell

Solar panel refers either to a photovoltaic module, that generates the voltage based on the input light to a set of solar photovoltaic (PV) modules are electrically connected and mounted on a supporting structure. A PV module is a packaged, connected assembly of solar cells. Solar panels can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. This module uses high quality multiple solar cells. They make excellent battery trickle chargers and small power supplies. Some of the uses for a 3 watt solar module are charging batteries for telemetry, fence chargers, automatic feeders, electric gates or for battery maintenance. This unit comes with a 3 Meters of cord. Use this 3 watt solar panel to charge a Rechargeable battery, ideal for low power applications. The input power is 3 watts and the working environment temperature is -10˚c to 60˚c. In this approach small solar panel is used instead of LDR because the functioning of both components is same.

4.2. Designing of PI Controller

LabVIEW PID toolset features a wide array of VIs that greatly help in the design of a PID based control system. Control output range limiting, integrator anti-windup and bump less controller output for PID gain changes are some of the salient features of the PID VI. The PID Advanced VI includes all the features of the PID VI along with non-linear integral action, two degree of freedom control and error-squared control. PID palette also features some advanced VIs like the PID Auto tuning VI and the PID Gain Schedule VI. The PID Auto tuning VI helps in refining the PID parameters of a control system. Once an educated guess about the values of P, I and D have been made, the PID Auto tuning VI helps in refining the PID parameters to obtain better response from the control system.In this design the Derivative value taken as zero hence the controller named as PI controller.

4.3. Designing of Fuzzy Controller

Fuzzy logic is a method of rule-based decision making used for expert systems and process control. Fuzzy logic differs from traditional Boolean logic in that fuzzy logic for partial membership is a set. Fuzzy controller is fuzzy code designed to control something, usually mechanical. They can be hardware or software and can be used in anything from small circuit to large mainframes. Fuzzy controllers are very robust, can be easily modified, can use multiple inputs and outputs sources. It is much simpler than its predecessors (linear algebraic equations), also these are very quick and cheaper to implement.

There are basically 5 steps involved in the designing of a fuzzy controller. They are

i. Identifying the number of inputs and outputs.
ii. Determining the range of inputs and outputs.
iii. Creating the membership functions for input and output.
iv. Defining the Linguistic variables.
v. Specifying the rule table.
vi. Writing the design rules which follows typical if-then form and at last
vii. Checking the test results. First fuzzify the data or create membership values for the data and put them in fuzzy sets, we have to divide each set of data into ranges.

Here in this paper, the design of the fuzzy controller is done as follows:
The inputs to design the controller are

i. PV voltage
ii. Error, which is obtained by subtracting the set point value from the current PV voltage. And the resultant output of this system is in terms of voltage which controls the light source.

The range of PV and error are defined and membership functions are defined to the respective inputs.Then the linguistic variables are defined for each input separately to improve the performance of controller. Then the range of output is defined as well as linguistic variables are defined to the voltage range.

Figure 4. Membership functions and linguistic variables of PV and Error

Typically a fuzzy controller has at least two inputs and one output. Here the two defined inputs are PV and error and the respective output is defined as voltage. To relate these two inputs and output parameters, here we use fuzzy sets to represent the exact relation between outputs to the respective inputs.

Here the fuzzy rule base is the fundamental to synchronize the inputs and the output to fire the exact output for the required input, the if-then rule base works perfectly to showcase the working of the fuzzy in efficient manner.

LDR \ ERROR	VVH	VH	H	M	L	VL	VVL
VVVH	VVHR	VHR	HR	M	LR	VLR	VVLR
VH	VVHR	VHR	HR	M	LR	VLR	VVLR
H	VVHR	VHR	HR	M	LR	VLR	VVLR
M	VVHR	VHR	HR	M	LR	VLR	VVLR
L	VVHR	VHR	HR	M	LR	VLR	VVLR
VL	VVHR	VHR	HR	M	LR	VLR	VVLR
VVVL	VVHR	VHR	HR	M	LR	VLR	VVLR

Figure 5. Fuzzy set for inputs (PV, error) v/s output (voltage)

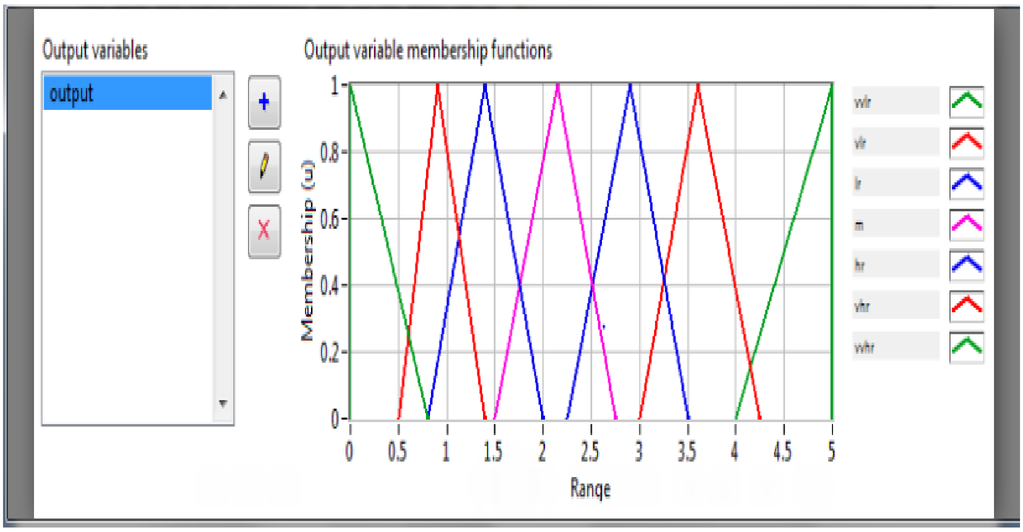

Figure 6. Membership functions and linguistic variables of Output Depending on this fuzzy set the rules are written for the fuzzy controller. The ranges you determine for each set of data can drastically determine how well the controller works. The rule table must be created to determine which output ranges are used. The table is an intersection of the two inputs. Now we have to figure out what to do with the result we get from the rules and the fuzzy sets. The typical way is to defuzzify using Mamdani's center of gravity method (COG).

Mamdani's center of gravity method principle takes the input values (PV and error) and finds where they intersect their sets. The intersection creates a cut-off line known as the alpha cut. We fire our rules to find the corresponding output rule. The rule is then cut-off by the alpha cut, giving us several triangular shapes. These shapes are added together to find their total centre of gravity.

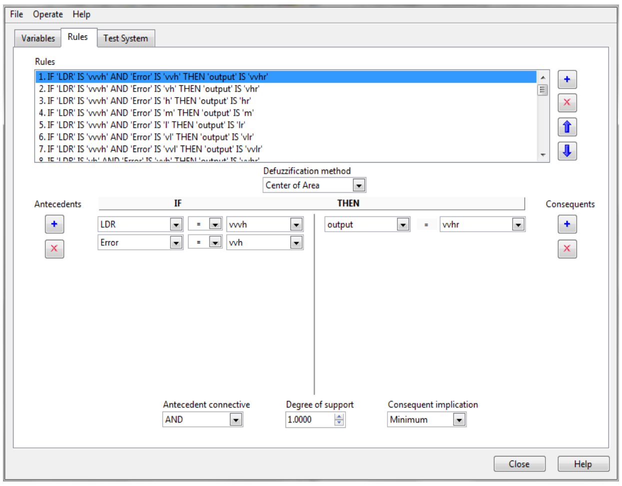

Figure 7. “If then” Rules based on fuzzy set in Mamdani’s (COG)

Thus the designing of controller part is finished by following all the steps discussed above.

4.4. Lighting Source

Here LED lighting system is used. LED (Light Emitting Diodes) are the newest, most energy efficient lighting source available. Because of their tremendous efficiencies, the LED lighting technology is revolutionizing illumination. From the back lighting on your keyboard to the street lights outside of your home - LEDs are more and more rapidly being integrated.

4.5. Experimental Setup

Figure 8 shows the experimental setup of virtual PI controller.it consist of a solar panel DAQ unit and LabVIEW pi controller and light source. The present light is read by the PV cell and given to the PI controller by the DAQ unit, then based on the present light condition the controller will takes the action.

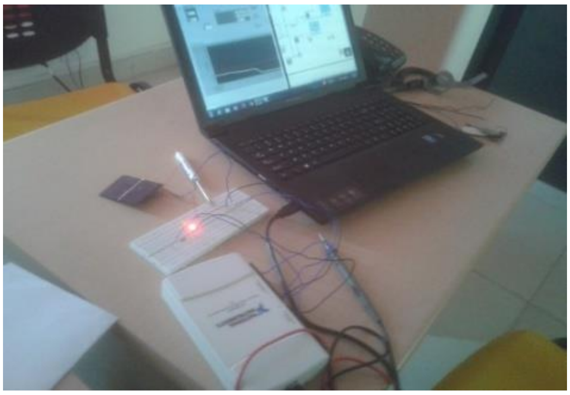

Figure 8. Experimental setup of virtual controller

5. Results and Discussions

5.1. Response of PI Controller

Solar panel is interfaced to DAQ to reads the present light intensity. The light intensity can be controlled by using PID virtual controller. It will calculate the error and so that it will decides the output. Here K_p, and K_i are the gain constants of proportion and integral modes respectively. Based on the received input voltage and set point the controller will takes the action to produce required output voltage.

Here the controller action is tested for three different set points. From all the three graphs it is observed that, whenever there is gradual change in the input the output voltage produced by the controller will change. When the input voltage reaches the set point the output voltage also reaches set point and then after due the decrement in the input voltage, the output is gradually increasing then after it will settle.

Here the graph shows the controller action for three different set points. For example consider the figure 9 it is tested for set point of 0.5 volts, when the input voltage lesser or equal than the 0.5 volts the controller will takes the action and it will increases the output voltage. From the above graph it is observed that at the instance of exactly 18th sec the input voltage i.e, the the voltage from the pv cell is less than the 0.5 volts then the controller increases the output voltage gradually. Again the instance of 20th sec the input voltage is lesser than the 0.5 volts and then maintaining constant, then the controller also produces the gradual output voltage upto 20th sec, from the 20th sec it is producing the constant voltage.

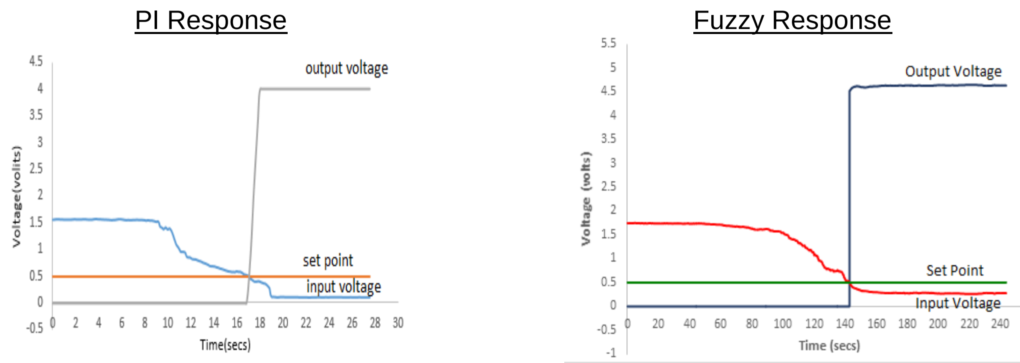

Figure 9. Servo response of system for a set point voltage of 0.5 volts

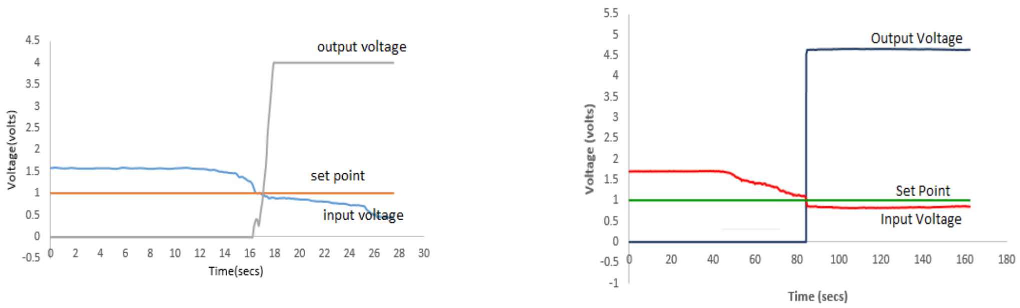

Figure 10. Servo response of system for a set point voltage of 1 volts

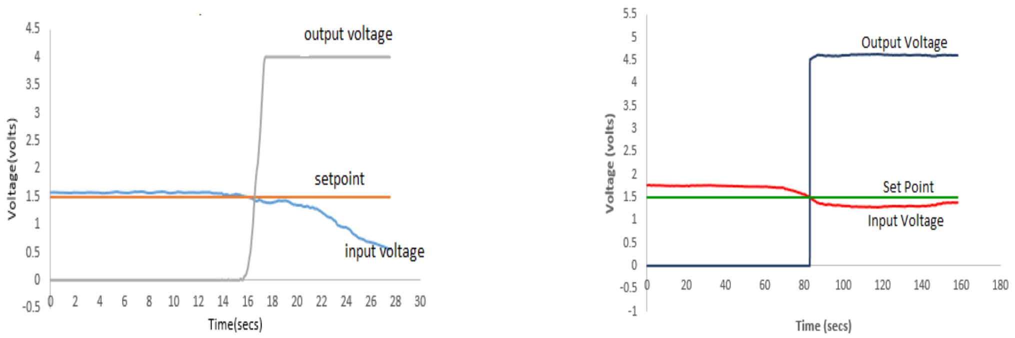

Figure 11. Servo response of system for a set point voltage of 1.5 volts

The PI control algorithm is widely used algorithm in industries because it is simple and roboust.This algorithm is sufficient get excellent results in a variety of applications and it is also one of the main reasons for the continued use over the years. NI LabVIEW and NI plug-in DAQ devices offer higher accuracy and better performance to make an excellent PI control system.These are the values of the controller proportional gain K_p is 6.4299 and the integral gain K_i of the controller is 0.002928.

5.2. Response of Fuzzy Controller

The output results are acquired by imitating a real time setup which includes a fully equipped system with the NI LabVIEW software installed in it, with a DAQmx-6211 card to acquire the analog form of data from the PV sensor and to convert it to digital form, also the actuator is required to get the optimal output which in this case is a light source.The experimental investigations in NI LabVIEW show that the new system developed would be highly flexible and easy in controlling the level. This new system will create a new era in the field of Process Automation.

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