SERBIAN JOURNAL OF ELECTRICAL ENGINEERING
Vol. 12, No. 2, June 2015, 171-182

UDC: 519.977:597]:004.42MATLAB **DOI: 10.2298/SJEE1502171R**

Fuzzy Logic Based Control System for Fresh Water Aquaculture: A MATLAB based Simulation Approach

Dinesh Singh Rana[1], Sudha Rani[1]

Abstract: Fuzzy control is regarded as the most widely used application of fuzzy logic. Fuzzy logic is an innovative technology to design solutions for multi-parameter and non-linear control problems. One of the greatest advantages of fuzzy control is that it uses human experience and process information obtained from operator rather than a mathematical model for the definition of a control strategy. As a result, it often delivers solutions faster than conventional control design techniques. The proposed system is an attempt to apply fuzzy logic techniques to predict the stress factor on the fish, based on line data and rule base generated using domain expert. The proposed work includes a use of Data acquisition system, an interfacing device for on line parameter acquisition and analysis, fuzzy logic controller (FLC) for inferring the stress factor. The system takes stress parameters on the fish as inputs, fuzzified by using FLC with knowledge base rules and finally provides single output. All the parameters are controlled and calibrated by the fuzzy logic toolbox and MATLAB programming.

Keywords: Fuzzy logic controller, Fuzzy interference systems, ANFIS.

1 Introduction

In the world fishes are living into the natural water and because of that they are facing many diseases. These diseases occurred due to change in parameters i.e. dissolved oxygen, ammonia, nitrogen, carbon dioxide, calcium, ozone, hydrogen sulphide, pH present into the water. If these parameters vary abruptly changes, the fishes get affected by the several diseases. The fish farmer can control the rearing conditions so as to increase the productivity and the quality of the aquatic organism produced and this production is also independent of environmental impacts. The risk of diseases entering into the system is minimized as well as the chance of fish escaping. Due to improved water purification systems, the release of nutrients and waste water can be reduced considerably [1]. There is potential for marine pollution from marine cage

[1]Department of Instrumentation (Formerly I.I.E), Kurukshetra University, Kurukshetra India;
E-mail: dineshsrana24@rediffmail.com

farming fish from discharge of uneaten food and excreted material which results in organic enrichment of the sediments below the cages and hyper-nitrification and oxygen depletion in the water column [2]. It is well known that fish have a low food conversion rate and feeding represents the most important expenditure, approximately 40% of total production cost. Therefore, precise quantities of food should be provided to avoid water pollution and economic losses due to food waste when water conditions are inadequate for fish feeding [3].

Stress factor on the fish is an important parameter which gives information about the overall healthiness of the fish and the correctness of the methods adopted during the pond management. There is no direct tool or a model to measure this stress parameter. Fuzzy logic controller (FLC) provides a method to construct controller algorithms in a user-friendly way closer to human thinking and perception which can reduce the controller development time. The main advantage of Fuzzy based control is that no parameter identification is required as compare to other control strategies available [4]. Fuzzy logic is invariable used in system control and analysis design, because it shortens the time for engineering development and sometimes in the case of highly complex system. Fuzzy logic proved to be a valuable tool for translating the dive log data into quantitative form [5]. Temperature, salinity, photoperiod, pH, dissolved oxygen, water flow and water level were monitored and controlled in a closed, recirculating seawater raceway [6]. A fuzzy logic-based expert system replaced the classical process control system for operation of the bioreactor, continuing to optimize de-nitrification rates and eliminate discharge of toxic by-products [7]. Fuzzy systems have also been employed in order to model complex interactions of habitat variables and reflect expert knowledge [8]. Fuzzy controller can be designed without having the thrust force, by using intuitive data and human experience as fuzzy rules [9, 10].

Fuzzy-logic-based methods and fuzzy logic formalism have been demonstrated as appropriate to address the uncertainty and subjectivity in complex environmental problems [11]. This proposed system “Fuzzy logic controller for fresh water aquaculture” takes three stress parameters variables temperature, dissolve oxygen (DO) and conductivity as inputs in crisp form and converts these variables into single fuzzified output. Fuzzy logic controller system, control these input stress parameters and get output as a % health of fish which work as display effect of deflection in temperature, dissolve oxygen and conductivity on health of fish. This fuzzy logic system uses fuzzy toolbox in MATLAB and program has been written in MATLAB to implement the system. This process based system can also be controlled by using PLC but cost of hardware required would be too high [12].

2 Methodology and Development of Fuzzy Inference Systems

Fuzzy inference system (FIS) performance is evaluated by using the Fuzzy Logic Controller block in a Simulink model of system. The Fuzzy Logic Controller block automatically generates a hierarchical block for fuzzy inference systems. This representation uses only built-in Simulink blocks, enabling efficient code generation using Real-Time Workshop which is available separately. FIS can be saved in ASCII format for application of data outside the MATLAB environment. **Table 1** shows asset of the stress parameters for fresh water aquaculture [13].

Table 1
The stress parameter ranges for fresh water aquaculture.

Parameters	Desirable Ranges	Acceptable Ranges
Dissolved oxygen	5–8 ppm	5–12.12 ppm
Temperature	65°F–75°F (20°C–35°C)	35°F–85°F (2°C–30°C)
Conductivity	100–2000 μS/cm	30–5000 μS/cm

The toolbox supplies a fuzzy inference engine with inputs that execute fuzzy system as a stand-alone application or can be embedded in an external application. For simulation, a program was developed in MATLAB with commands whose output predicts the effect of parameters on health of fish. A special function name fish was created. By this function one can get output directly by entering the various inputs. The output of the FIS is forwarded as input command to the process or system and output of the system is sensed by the sensor. If all stress factor is controlled according to specifications, then process is complete controlled otherwise the whole process has to be retune using input parameters i.e. stress factors (temperature, dissolve oxygen, conductivity). This simulation can also be done MATLAB toolbox having facility of graphically simulation. Initially three inputs were identified (Temperature, DO, conductivity) and only one output i.e. % of fish health.

The first and foremost step is to obtain the fuzzification of inputs and output. For this a membership function is to be identified, so triangular membership function of inputs and output is selected. Afterwards three inputs stress parameters were identified i.e temperature, dissolve oxygen, conductivity. All these stress parameter have three stress factor i.e. low, medium, high. The percentage of fish health consists of three conditions bad, average and good condition. **Table 2** shows the ranges of various stress factor membership functions.

Table 2
The ranges of various stress factor membership functions.

Stress Parameters	Low	Medium	High
Temperature	0–20	10–30	20–50
Dissolve oxygen	2–10	4–15	10–20
Conductivity	0–2	1–4	2–6

Table 3
The output effect on fish.

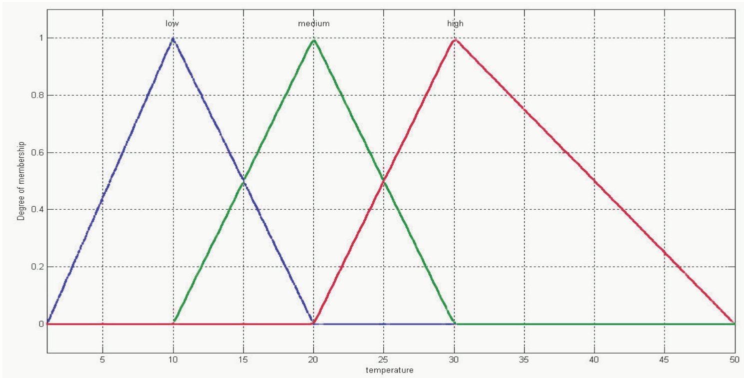
Percentage of fish health	Bad	Average	Good
	0–40%	20–60%	40–100%

These are the specific range of stress factor of the stress parameters for the fish health. Most of the rules fire between these inputs and one can predict the stress factor on the fish. If the range is 0 – 20 that means temperature is low, if the range is 10 – 30 that means temperature is medium and if the range is 20 – 50 that means temperature is high. Similarly to the temperature ranges dissolve oxygen and conductivity ranges were also specified for various stress factors.

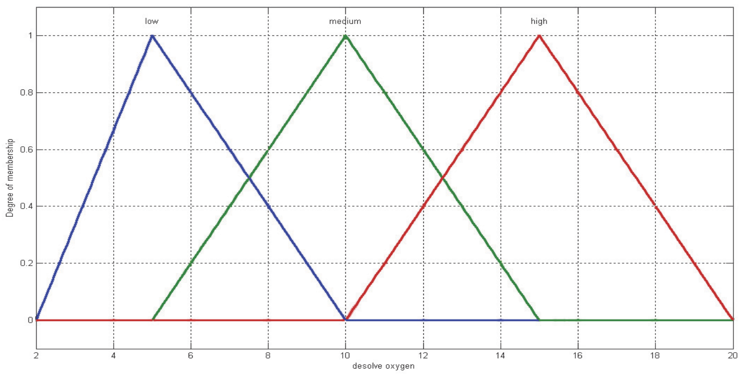
According to the ranges for conditions of the fish one can predict the health of fish i.e. bad, average, and good **(Table 3)**. The main objective of fuzzy based aquaculture is to maintain in good condition for fish, therefore parameters such as temperature, dissolve oxygen and condition must be adjusted accordingly. If the value of input variables is not suitable for good health of the fish, then that input variable has to be replaced.

There are three membership functions for temperature, dissolved oxygen and conductivity. i.e., low, medium, and high. Each of these stress factors has different range. The type of membership function selected is triangular. Fig. 1 depicts the membership function for input variables (temperature, dissolve oxygen and conductivity).

The O/P triangular membership functions for percentage of fish health is shown in Fig. 2. There are three membership functions for percentage of fish health and it consists of three stress factors i.e. low, medium, and high. These stress factors have different ranges. The type of membership function selected for output is also triangular. The output action words are Bad, Average, and Good. There exist a rule editor window through which one can add various linguistic rules for number of inputs and single output weight. The linguistic rule comprises of two parts i.e first part ‘IF-And’ which is antecedence and second part ‘Than is’ which is consequence.

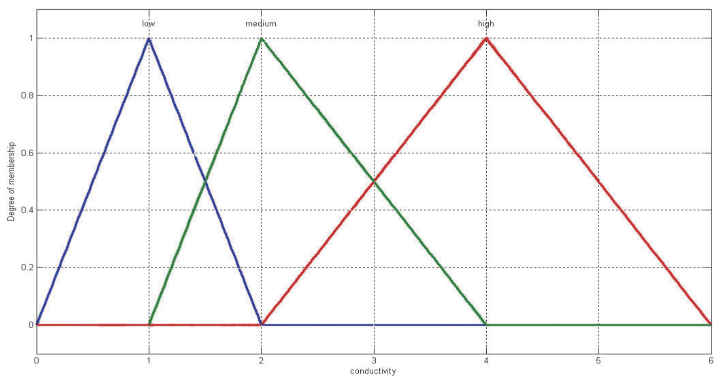


(a)



(b)

Fig. 1 – *Membership function for stress parameters:*
(a) *Temperature*, (b) *Dissolve oxygen*.



(c)

Fig. 1 – *Membership function for stress parameters:*
(a) *Temperature*, (b) *Dissolve oxygen*, (c) *Conductivity*.

Figs. 3 and 4 represent the rule viewer window and the model structure of ANFIS. This window provides mapping between input stress parameters and output can be observed. The rule viewer displays the all part of the fuzzy inference process from inputs up to outputs. Each row of plots corresponds to one rule, and column of plots specifies to either an input variable (yellow, on the left) or an output variable (blue, on the right). One can modify the system input window by moving the long yellow index lines that go down each input variable's column of plots. By clicking on each node one can observe the detailed information about inputs, output, and rules of the FIS. The simulation of whole process is illustrated in flow chart depicted in Fig. 5.

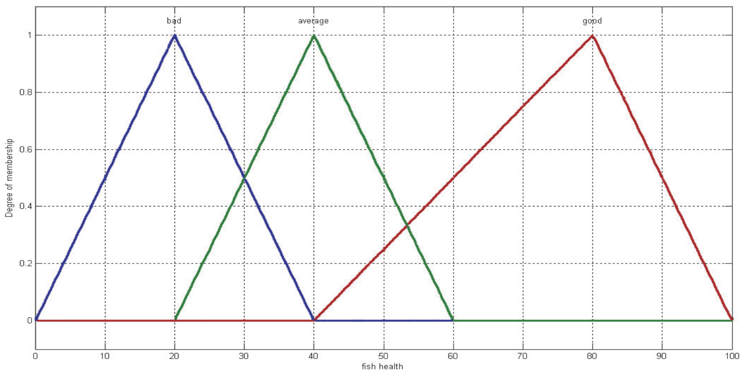


Fig. 2 – *The membership function for output (Percentage of fish health).*

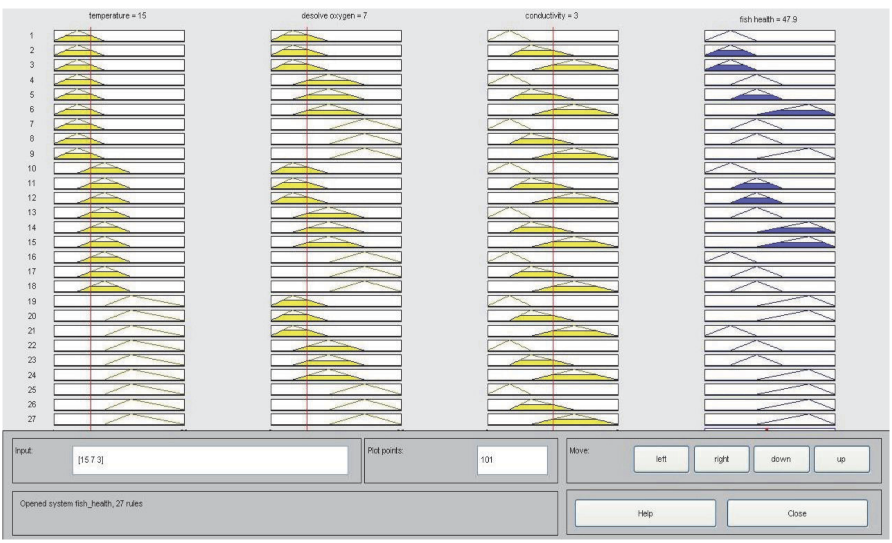


Fig. 3 – *Rule viewer in fuzzy logic toolbox.*

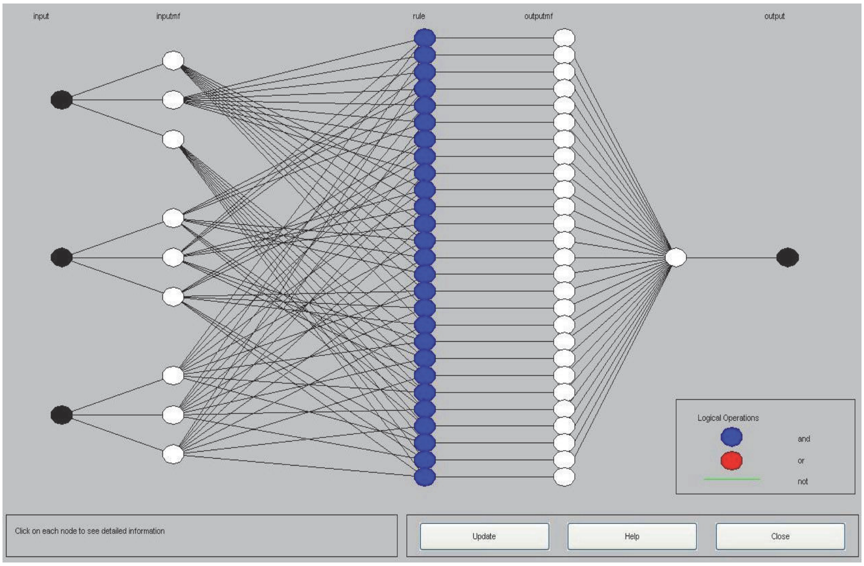


Fig. 4 – *Model structure of ANFIS.*

Firstly a new fuzzy interference system has been built which given the name fish health. After then the membership function for input variable i.e. Temperature, Dissolve Oxygen, Conductivity and for output i.e. percentage of fish health has been added to it. Twenty seven (27) IF AND THEN rules between input and output membership function has been defined and added these rule list to fish health fuzzy interference system.

Some of these rules are;

- If (temperature is low) and (dissolve oxygen is low) and (conductivity is low) then (fish health is bad)
- If (temperature is low) and (dissolve oxygen is medium) and (conductivity is medium) then (fish health is average)
- If (temperature is low) and (dissolve oxygen is high) and (conductivity is medium) then (fish health is average)
- If (temperature is low) and (dissolve oxygen is medium) and (conductivity is high) then (fish health is good)
- If (temperature is medium) and (dissolve oxygen is low) and (conductivity is low) then (fish health is bad)
- If (temperature is medium) and (dissolve oxygen is medium) and (conductivity is low) then (fish health is average)
- If (temperature is medium) and (dissolve oxygen is medium) and (conductivity is medium) then (fish health is good)
- If (temperature is high) and (dissolve oxygen is low) and (conductivity is medium) then (fish health is average)

- If (temperature is high) and (dissolve oxygen is low) and (conductivity is high) then (fish health is average)
- If (temperature is medium) and (dissolve oxygen is high) and (conductivity is medium) then (fish health is good)
- If (temperature is high) and (dissolve oxygen is high) and (conductivity is medium) then (fish health is good)
- If (temperature is high) and (dissolve oxygen is low) and (conductivity is low) then (fish health is bad)

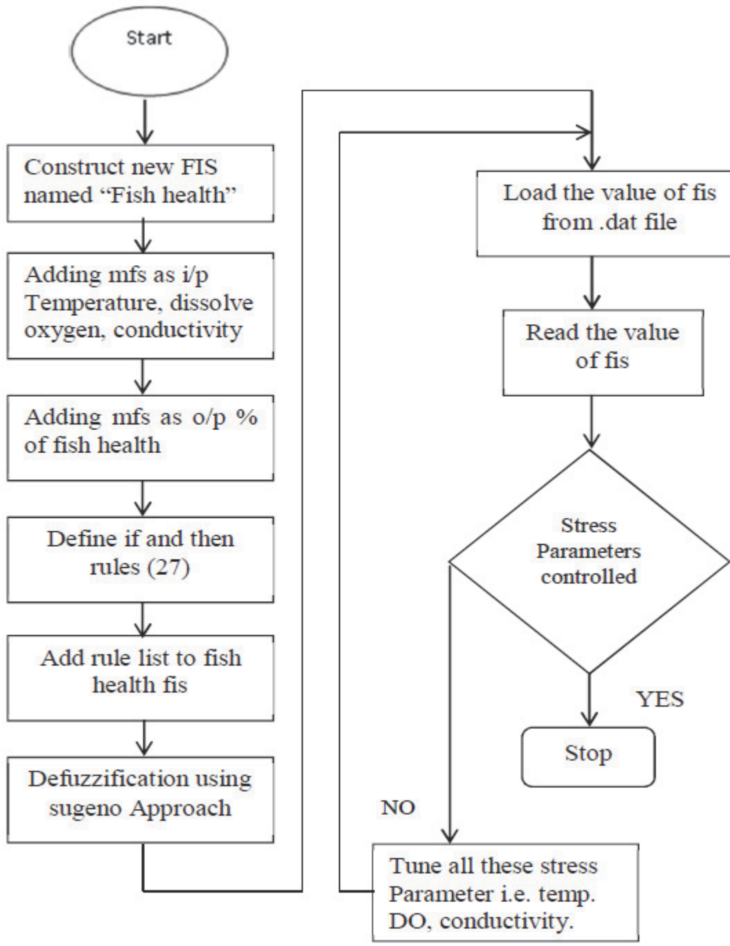


Fig. 5 – *Simulation flow chart for FLC system for fresh water Aquaculture.*

Centroid method mostly used for defuzzification of the fuzzified output of the fuzzifier. The defuzzification converts the fuzzy value into crisp value which is required for process (plant). The values of FIS loads from the .dat file and read the value form this file. These different values of input variables temperature, dissolve oxygen, conductivity loaded from file and predict the stress factor. If the stress factor are controlled then the process is complete otherwise all parameters tunes and these values load again into .dat file and entire process starts controlling again.

3 Simulation

The final step starts with saving of Training data and verifying it. The Training data is stored in file, which saves in .dat form. Similarly the checking data file also stored in dat form. From these two files one can save the training and checking data from file into a disk. In .dat data file four column are present in which first three columns represents input parameters and last column indicates a single output for training data. In this window a graph between data set index and output can be observed. The Figs. 6 and 7 predicts the training and checking data output. With help of Adaptive Neuro-Fuzzy Inference System (ANFIS) Editor, membership functions can be shaped by training them with input/output data rather than specifying them manually. The toolbox uses a back propagation algorithm alone or in combination with a least squares method, enabling fuzzy systems to learn from the data. Error occurs between load checking data and test FIS checking data can be viewed in ANFIS Editor Window.

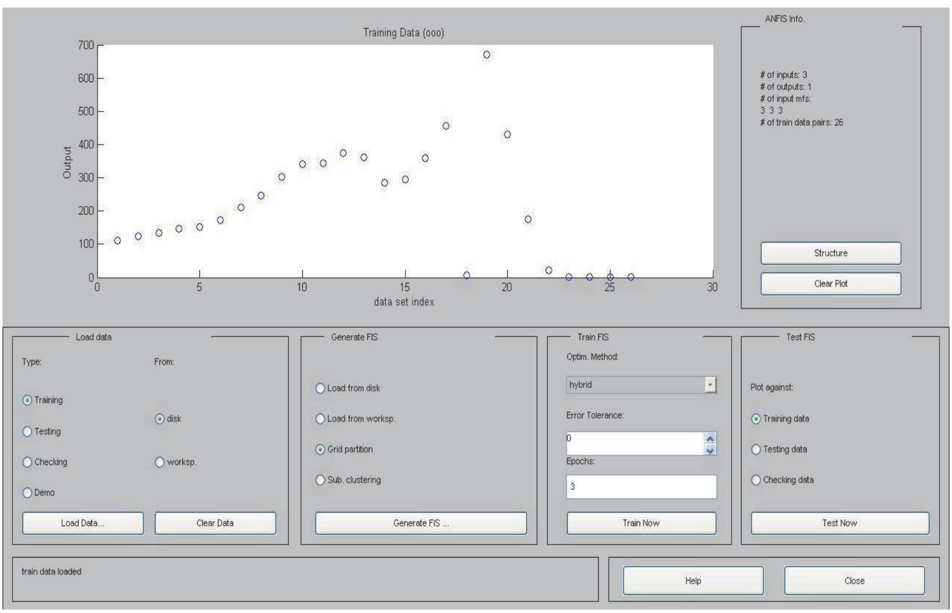


Fig. 6 – *Training data output.*

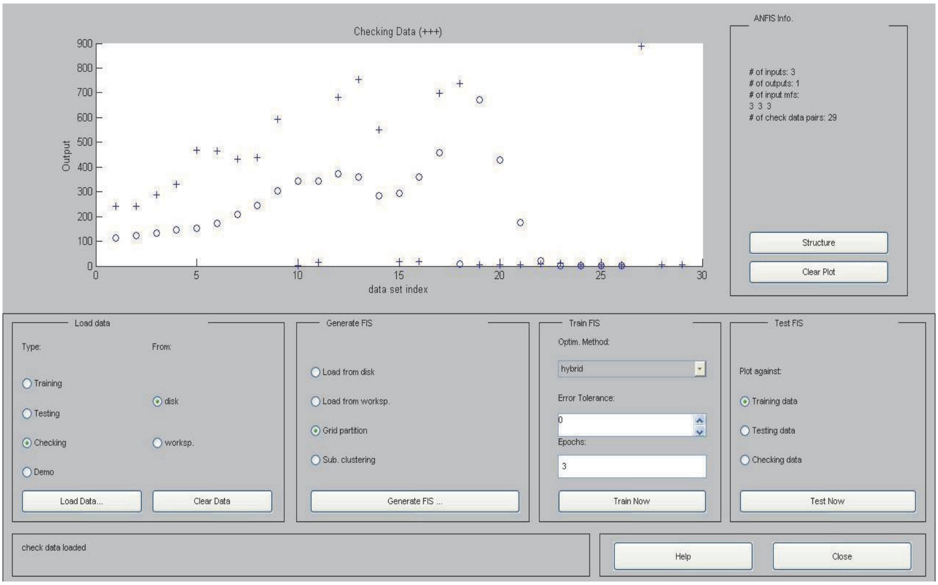


Fig. 7 – *Checking data output.*

4 Results

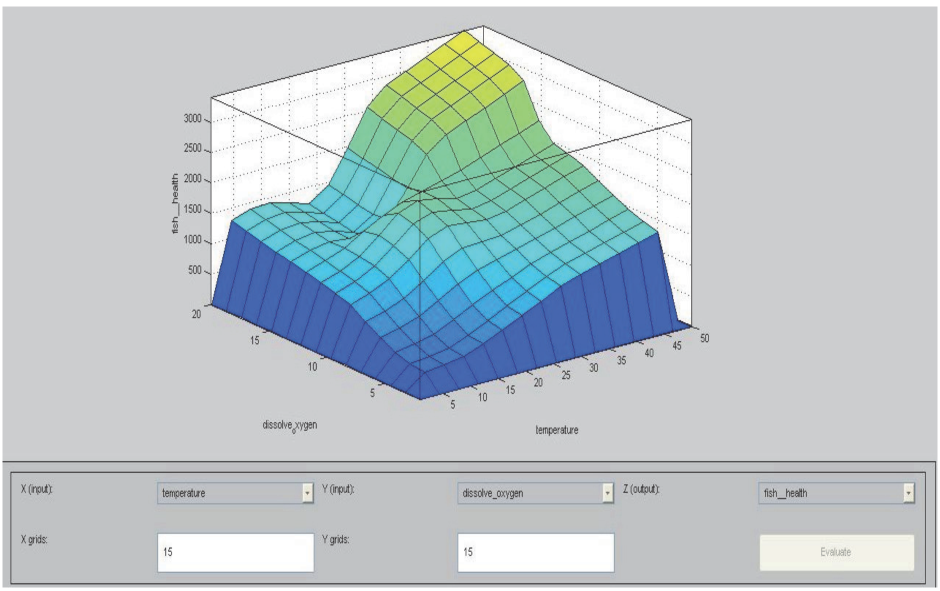


Fig. 8 – *Surface viewer.*

The surface viewer is a GUI in MATLAB tool box that examines the output surface of a fuzzy inference system (FIS) for any one or two inputs (Fig. 8). Since it does not alter the fuzzy system or its associated FIS matrix in anyway, it is a read-only editor. By clicking on the plot axes and dragging the mouse, surface can be manipulated to view it from different angles. From the surface plot one can conclude that the feeding percentage increased, when the dissolved oxygen was above 75% and decreases when it goes below this marked percentage. The feeding percentage decrease substantially, when temperature decreases below 25°C. So from this point of view FLC based control maintain the feeding percentage by controlling the temperature and oxygen thus maintaining the good health of fish in the water body.

5 Conclusion

In present paper, an attempt has been made to apply fuzzy logic to derive on-line stress parameters on the fish and their control. Fuzzy logic control system controls input stress parameters such as temperature, dissolve oxygen and conductivity and get output display as a % health of fish. Developed system presents a display that show deflection in temperature, dissolve oxygen and conductivity on health of fish as output. Thus by implementing the FLC in the MATLAB with the help of fuzzy logic toolbox and MATLAB programming can be utilized to control the various stress factors on the fish. This manuscript considers only three input parameters dissolved oxygen, temperature and conductivity. Some more parameters such as dissolved ammonia and carbon dioxide may be included in order to get better degree of accuracy.

6 References

[1] A. Baer: Modeling of Growth and Mortality of Turbot Reared in Marine Recirculation Aquaculture Systems, PhD Thesis, University of Kiel, Germany, July 2010.

[2] J.M. Navas, T.C. Telfer, L.G. Ross: Spatial Modeling of Environmental Vulnerability of Marine Finfish Aquaculture using GIS-based Neuro-fuzzy Techniques, Marine Pollution Bulletin, Vol. 62, No.8, Aug. 2011, pp. 1786 – 1799.

[3] G. M. Soto-Zarazu, E. Rico-Garcıa, R. Ocampo, R.G. Guevara-Gonzalez, G. Herrera-Ruiz: Fuzzy-logic-based Feeder System for Intensive Tilapia Production, Aquaculture International, Vol. 18, No. 3, April 2010, pp. 379 – 391.

[4] G.K. Sylaios, T. Koutroumanidis, A.C. Tsikliras: Ranking and Classification of Fishing Areas using Fuzzy Models and Techniques, Fisheries Management and Ecology, Vol. 17, No.3, June 2010, pp. 240 – 253.

[5] A.M Gaur, R. Kumar, A. Kumar, D.S. Rana: PLC based Automatic Control of Rheometer, International Journal of Control and Automation, Vol. 3, No. 4, Dec. 2010, pp. 11 – 20.

[6] R. Sharma, D.S. Rana, A.M Gaur: A Fuzzy Logic based Automatic Control of Rotary Crane (A Simulation Approach), Advanced Materials Research, Vol. 403-408, Nov. 2011, pp 4659 – 4666.

[7] D.L. Angel, P. Krost, W.L. Silvert: Describing Benthic Impacts of Fish Farming with Fuzzy Sets: Theoretical Background and Analytic Methods, Journal of Applied Ichthyology, Vol. 14, No. 1-2, Juy 1998, pp. 1 – 8.

[8] P.G. Lee: A Review of Automated Control Systems for Aquaculture and Design Criteria for Their Implementation, Aquaculture Engineering, Vol. 14, No. 3, 1995, pp. 205 – 227.

[9] P.G. Lee, R.N. Lea, E. Dohmann, W. Prebilsky, P.E. Turk, H. Ying, J.L. Whitson: Denitrification in Aquaculture Systems: An Example of a Fuzzy Logic Control Problem, Aquacultural Engineering, Vol. 23, No. 1-3, Sept. 2000, pp. 37 – 59.

[10] S. Fukuda, N. Onikura, B. De Baets, W. Waegeman, A.M. Mouton, J. Nakajima, T. Mukai: A Genetic Takagi-Sugeno Fuzzy System for Fish Habitat Preference Modelling, Second World Congress on Nature and Biologically Inspired Computing, 15-17 Dec. 2010, Fukuoka, Japan, pp. 274 – 279.

[11] A.R. Alamdar, M.R. Dehghani, A. Alasty: Modeling of Tail Dynamic Behavior and Trajectory Control of a Fish-Robot using Fuzzy Logic, IEEE International Conference on Robotics and Biomimetics, 14-18 Dec. 2010, Tianjin, China, pp. 885 – 890.

[12] D.S. Rana, R. Sharma: Fuzzy Logic based Automation of Green House Environmental parameters for Agro-industries - A Simulation Approach, International Journal of Applied Engineering Research, Vol. 6, No. 5, 2011, pp. 662 – 666.

[13] C. Gautam, S. Sadistap, P. Kumar, K.S.N. Rao: LabVIEW based Automatic Measuring System for Fresh Water Aquaculture Parameters, International Journal of Scientific and Engineering Research, Vol. 5, No. 2, Feb. 2014, pp. 1390 – 1394.