# The Fuzzy Inference System for Intelligent Water Quality Monitoring System to Optimize Eel Fish Farming

Sri Wahjuni[1)], Ardhi Maarik[2)], Tatag Budiardi[3)]
[1,2)]Department of Computer Science [2)] Department of Aquaculture
Bogor Agricultural University
[1)] my_juni04@ipb.ac.id

***Abstract*—Eel is a high economic value commodity. International market demand for this fish is high enough, so a lot of farmers cultivated it with main objective of export. The problem in eel fish farming is the seeds that have to be taken directly from nature. This impacts to the more rapidly declining of eel seeds availability. Another problem in the cultivation of eels is how to control and create environments that match the eels natural habitat. This research This research aims to control some cultivation environment parameters such as pH, dissolved oxygen, and temperature. This system has been developed in an embedded system that connects some sensors with a single board computer (SBC) through a microcontroller. A fuzzy inference system algorithm is implemented on the SBC to control the process intelligently. As an integrated remote monitoring system, the data are sent to the server, then the user could have a real time information of environmental water condition of eels.**

***Keywords*— cultivation, eel, embedded systems, fuzzy inference, intelligent controller**

## I. Introduction

ish is a relatively abundant aquatic result commodity for maritime countries. Besides protein, fish contains nutrients that are good for the human body construction, particularly the brain intelligence improvement. One type of fish that contains good nutrients is eel that has a high protein content [1][2]. This fish also have high selling price on market [1]. Therefore, this fish becomes a prospective export commodities for eel producers in Indonesia. Some of those international markets Some of those international markets are Japan, Netherlands, China, Taiwan, and Korea [1]. Unfortunately, FAO estimated production of this fish decreased from 2000 to 2016 [3].

Indonesia is one country that has abundant resources of eel and wherein eel has a broad distribution of ecosystems [4]. There are six species of eels in Indonesia of about 17 species in the world. Two species of eel that are widely cultivated in Indonesia are Anguilla bicolor and A.marmorata [5]. The growing up eels process that are in nature are replace by in fresh waters, such as rivers. In order to perform a katadromous process [6], eels migrating to the sea for spawning and reproduction. This is why eels can not be bred in in the entirely hatchery, but only to be grown up with seeds taken from the wild eel directly.

Although Indonesia has abundant availability of eels seed, but it is not easy to cultivate these fish. Many factors must be considered for this eel fish farming. According to some experts, some factors impacts to the success in the cultivation of eels are the selection of good quality eel seed [1], appropriate feeding, and eel environmental controling. According Affandi [4] a decrease in environmental circumstances, especially in the dissolved oxygen and temperature also can be weaken the condition of the eel seeds during cultivation. When environmental conditions are not optimal, the probability of life of eels would be decreased.

For that reason we need to develop an automatic system that can be effectively carried out monitoring and controlling purposes independently to optimize cultivation. The relatively close work to this researc is Saaid et al.[7] that developed an automatic system to control indoor aquaponics. The work on smart monitoring of aquaponic also reported by Wang et al. that uses OpenWrt [8]. Fuzzy logic has also been used for embedded systems in terms of controlling the speed of rotation of the wheel [9]. Fuzzy can also be used to stabilize the system that controls are effective on real time systems to tuning parameters[10]. This research aims to design and implement an automated system for monitoring and controlling the quality of eels environment using fuzzy inference system for improving the survival of eel.

## II. Sidat (Eel)

Eel has a triangular head shape, the fins on the back of the head (the pectoral fins/pectoral) such as the ears, and also has a rounded (not sharp) tail shape. Every region in Indonesia has a different naming of the eel. Betawi people know him as the moa, sogila for Sulawesi, the hole for the Sundanese, the welus for Lampung region, as well as massapi for people of Papua and Ambon [1]. Some other names for eels are roll, uling, lumbon, larak, coax, gateng, embu, denong, laro, and luncah fish. Eel fish also known as unagi for Japanes and Korean. There are about 21 species of eels in the world [11], with the following classifications: Phylum : Chordata Class : Pisces Order : Apodes Family: Anguillidae Genus : Anguilla Species: Anguilla sp.

Eel has three stages of life, namely the oceans phase, estuaries phase, and the river phase. The first phase is the

978-1-5090-3840-4/16/$31.00 ©2016 IEEE

phase in which eel performs spawning in the oceans at a depth of about 300m and then the eggs hatch into larvae. In the estuary phase eel larvae are carried by ocean currents and metamorphose into small eels (glass eels). At the last phase, the small eel migrates towards the estuary and adapts to the new environment until reach the ELVER stage. During his life cycle, most of his time was spent on the river by adapting to change the pigment body color. At the end of its life cycle, the eel return to the sea.

Due to the complexity of life cycle of the eel, fish farmers believe eels breeding is not an easy work. One of the possible ways for fish culture is by way limited to the enlargement. Eel fish farming in Indonesia is divided into several stages, the first stage nursery , the second stage nursery, and the enlargement. At the first stage nursery the main focus is on the adaptation of eels to the new environment, which started from a glass eel to an ELVER. The second stage, also named as the ELVER stage, is a stage to wait for the eels to reach a fingerling size and ready for enlargement stage.

Several factors that influence the enlargement of eels are: the choice of good quality eel seeds [1], appropriate feeding, and controlling the eels life environmental.

## III. FUZZY SYSTEM

The control system developed in this study uses fuzzy inference system, which is able to control the environment more dynamic. Fuzzy is a mathematical principle for representing knowledge based on the degree of membership in the membership of which is certainly in binary representation [12]. The fuzzy process has several steps, the fuzzification, the system inference, and the defuzzification. In the fuzzification step, the crips variables are translate into the linguistic variables. In the second step, each input is mapped to an output with the terms set out in the knowledge base and rule base. Having mapped out each input variable to its output, its value is returned to the value of crips.

There are several terms in the fuzzy associated with the system will be created. The common terms are: fuzzy variables, fuzzy set, linguistic variables, fuzzy rules, the universe of discourse, domain membership functions, fuzzification, and defuzzification. As a conventional set, there are some basic operations to combine and modify the fuzzy set. There are three basic operators introduced by Zadeh (1965): operators AND, OR and NOT operator operator. AND operator is operated by taking the smallest value of fuzzy set, while the OR operator took the greatest value of the operations of fuzzy sets operated.

The results of fuzzy inference system (FIS) depend on what the fuzzy method is used. Output can be fuzzy values or constants. There are three methods well known in the fuzzy inference system. The first is the Tsukamoto method, which produces an output of fuzzy sets and defuzzification system used is the average weighted. The second is the Mamdani method, who issued the output of fuzzy sets and defuzzification method used is large of maximum (LOM), smallest of maximum (SOM), middle of maximum (MOM), and weigthed average. The last is the Sugeno method, which is in the process of inference generating constant output and defuzzification method used is the weighted average

## IV. THE SYSTEM ARCHITECTURAL DESIGN

The Architectural design of the system can be seen in Fig.1. The system has function as an intelligent control system as well as the environmental monitoring system of eel. The data are acquired by sensors that connected directly to the environment. The sensors attached to the Arduino microcontroller are a pH meter, a DO meter and a thermometer. Data from the sensors will be collected by the Arduino, and then be forwarded to the Intel Galileo as a single board computer (SBC). Using the SBC, these data will be processed by a fuzzy inference algorithm system. SBC is a necessity in this system because of the requirement of fast data computation in a realtime system.

Furthermore, the results of data processed by SBC would drive the actuator when needed. Actuator built in this study was limited to a simulation. In addition to provide instruction to the actuator, SBC also served as a gateway for accommodating and transmiting the data to the server. In turn, the system in the server receives the data and stores them in a database residing in the server. The data already stored in the server can be exploited further by the user, such as plotting them in a graphical form.

## V. THE FUZZY INFERENCE DESIGN

The architecture of the fuzzy inference system consists of input parameters, process and output. The input parameters are the degree of acidity, dissolved oxygen and temperature, as depicted in Fig.2. The FIS method used in this research is Tsukamoto. The output produced is a fuzzy set, while defuzzification used is the average. This output represents the survival rate of eels, which is the rate of live fish in a certain condition. FIS system planning is based on the expert justifications who performs data validation or fuzzy systems. The data used in this study can be seen in Table 1. The column of range defines the value that is allowabled by the system to be processed. The set point indicates the best value to be reached by the system to get an optimal condition. The category shows the grouping of the data based on the range. The fuzzy set column indicates the set model of each variable. The fuzzy set with three attributes is a set definition of a triangle shape while the fuzzy set with four attributes is a set definition of trapesium shape. Due to the limited space, in this


Fig. 1 *Architectural design of the system*

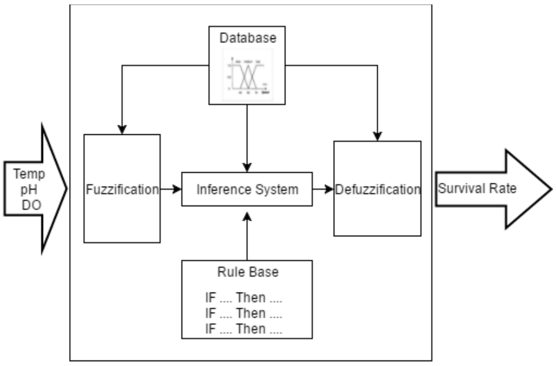


*Fig. 2 The architecture of the fuzzy inference system*

paper we only show the membership function of temperature as one of the input set as depicted in Fig.3.

The ouput of the FIS is used to define the survival rate using the rules listed in Table 2. The rules are composed using combination of categories of the three inputs.

To implement the designed model, the main program has been written in C++ programming language based on the flow diagram in Fig. 4. The module is loaded into the Intel Galileo.

Table 1 Model of fuzzy inference system

| Type | Name | Range | Set point | Category | Fuzzy set |
|---|---|---|---|---|---|
| *Input* | Temperature (ºC) | 20 - 35 | 29 | Cold | 20 – 28 (20, 20, 28) |
| | | | | Optimal | 20 – 35 (20, 28, 30, 35) |
| | | | | Hot | 30 – 35 (30, 35, 35) |
| | pH | 4 – 11 | 7 | Acid | 4.0 – 6.5 (4.0, 4.0, 5.0, 6.5) |
| | | | | Optimal | 5.0 – 8.5 (5.0, 6.5, 7.5, 8.5) |
| | | | | Alkali | 8.5 – 11.0 (7.5, 8.5, 11.0, 11.0) |
| | DO (mg/L) | 0 – 8 | 7 | Low | 0.0 – 5.0 (0.0, 0.0, 3.0, 5.0) |
| | | | | Optimal | 1.0 – 8.0 (3.0, 5.0, 8.0, 8.0) |
| *Output* | Survival rate (%) | 0 - 100 | - | Low | 0 – 40 (0, 0, 30, 40) |
| | | | | Medium | 30 – 70 (30, 40, 60, 70) |
| | | | | Optimal | 60 – 100 (60, 70, 100, 100) |

## VI. Prototype Development

The prototype of this system has been developed by assembling some components to become a circuit. The main components are a water filter, an aquarium pump, a pH meter,

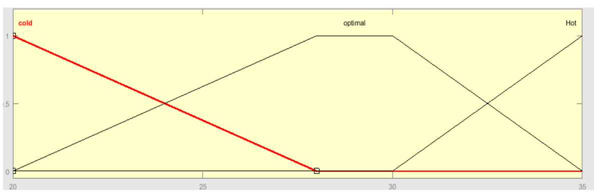


*Fig. 3 The fuzzy membership function of temprature*

Table 2 *Rules base*

| No | DO | pH | Temperture | SR |
|---|---|---|---|---|
| 1 | Low | Acid | Cold | Low |
| 2 | Low | Acid | Optimal | Medium |
| 3 | Low | Acid | Hot | Low |
| 4 | Low | Optimal | Cold | Medium |
| 5 | Low | Optimal | Optimal | High |
| 6 | Low | Optimal | Hot | Medium |
| 7 | Low | Alkali | Cold | Low |
| 8 | Low | Alkali | Optimal | Medium |
| 9 | Low | Alkali | Hot | Low |
| 10 | Optimal | Acid | Cold | Medium |
| 11 | Optimal | Acid | Optimal | High |
| 12 | Optimal | Acid | Hot | Medium |
| 13 | Optimal | Optimal | Cold | High |
| 14 | Optimal | Optimal | Optimal | High |
| 15 | Optimal | Optimal | Hot | High |
| 16 | Optimal | Alkali | Cold | Medium |
| 17 | Optimal | Alkali | Optimal | High |
| 18 | Optimal | Alkali | Hot | Medium |

a DO meter, a thermometer, an Arduino Uno microcontroller, and Intel Galileo SBC, and USB wireless modem. All the equipment are installed in an aquarium as fully illustrated in Fig. 5.

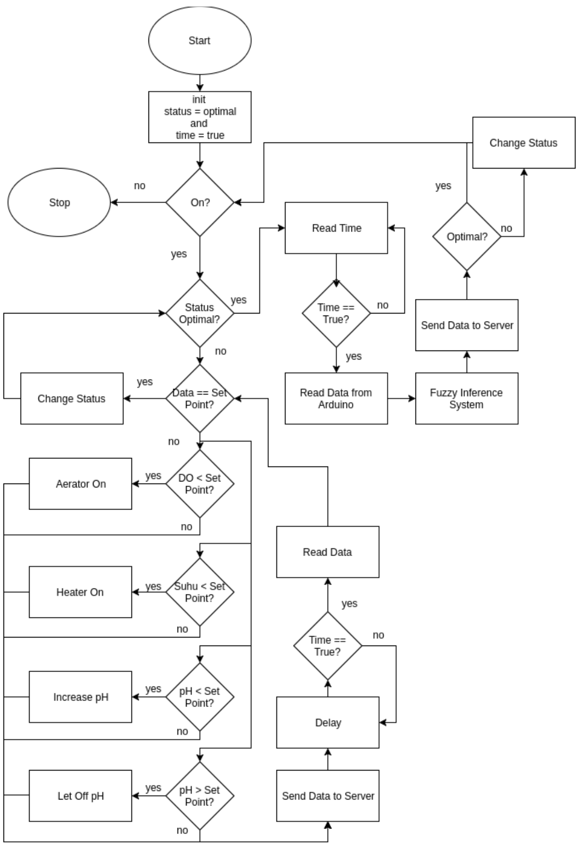


Fig. 4 *Main programme logic*

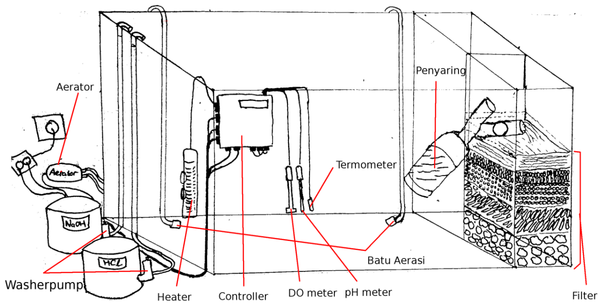


Fig. 5 *Equipments are installed*

## VII. RESULTS AND DISCUSSION

### A. Data Acquisition

Some calibration mechanisms are performed before the sensors are used. The graph in Fig. 6 shows the result of water temperature data acquitition taken for 24 ours (28-29 Juli 2016). The results of the data acquitition of pH and DO on the same date are presented in Fig. 7 and Fig. 8.

If we assume that the average of the data is the desired value, then the value of the precision of an instrument can be known through the standard error of the mean (SE mean), while accuracy can be known through the standard deviation of the data. Based on the aforementioned data collected the precision and accuracy of the sensors system are presented in Table 3. It can be seen that the average water temperature is 29.3000 ± 0.0186, the average water pH is 5.1751 ± 0.0363, while the average water DO is 5.9358 ± 0.0923.

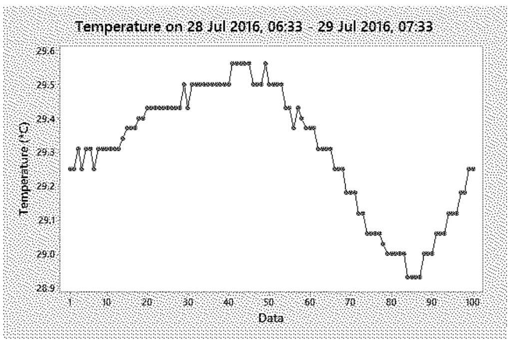


Fig. 6 *Data acquitition of temperature*

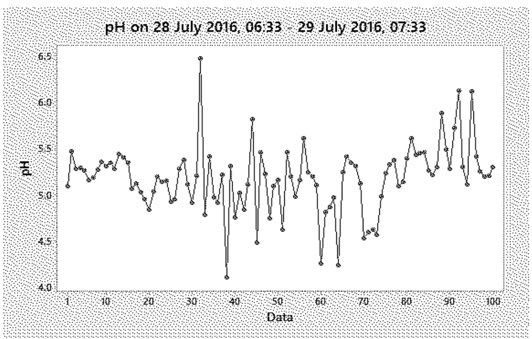


Fig. 7 *Data acquitition of pH*

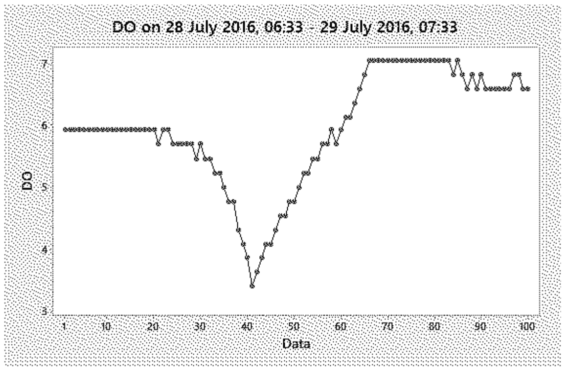


Fig. 8 *Data acquitition of DO*

The average pH value shown in Table 3 is relatively low, with the minimum value of 4. In our opinion, this is possible due to the unstable voltage problems. This is also shown by the fluctuated data as shown in Figure 7, although the precision of the obtained data is around 0.3632.

### B. The Response of The FIS Model

Some tests are conducted to simulate the response of the actuator when the environmental conditions are not good. The results are presented in Table 4.

Based on the environment measurement results, it is found that the simulated actuator run well. This is shown by the data presented in the column 'environment condition' in Table 4, which are indicated the output of the FIS for the measured parameters at the same row.

### C. Monitoring

The tests also perform to see how well the monitoring system runs. This system was developed on the platform of mobile applications as well as web applications. The capture of the monitoring system visualization can be seen in Fig. 9. The left one is the mobile version while the right one is the web version. The mobile version is built on android platform developed using Java programming language, while web version is developed using PHP programming language on Yii framework and combine with freeboard project. This system can display data stored in the server in a real time fashion. The data is updated regularly based on the environmental conditions sent by the SBC. The states of the survival rate monitored are divided into three conditions based on Table 2 namely, optimal for SR High, less than optimal for SR moderate and not optimal for low SR.

Table 3 T test result on the applience

| α | P-value | | | | | |
|---|---|---|---|---|---|---|
| | Temperature | | | | pH | DO |
| | salino–device | T1–device | T2–device | T3–device | device – Lab | device – Lab |
| 0.05 | 0.018 | 0.000 | 0.005 | 0.016 | 0.084 | 0.002 |
| 0.01 | 0.014 | 0.000 | 0.004 | 0.011 | 0.013 | 0.002 |

*) T1 : termometer 1; T2: termometer 2; T3: termometer 3

Table 4 Actuators activity 2016 -07-28

| Time | Condition | Data | | | Actuator status | | | Information |
|---|---|---|---|---|---|---|---|---|
| | | Temp | pH | DO | Temp | pH | DO | |
| 17:58 | Not good | 29.43 | 5.16 | 5.46 | 0 | 1 | 0 | Appropriate |
| 17:43 | Not good | 29.37 | 5.61 | 5.69 | 0 | 1 | 0 | Appropriate |
| 17:28 | Not good | 29.43 | 5.24 | 5.69 | 0 | 1 | 0 | Appropriate |
| 17:13 | Not good | 29.40 | 5.19 | 5.92 | 0 | 1 | 0 | Appropriate |
| 16:58 | Not good | 29.37 | 5.10 | 5.69 | 0 | 1 | 0 | Appropriate |
| 16:43 | Not good | 29.37 | 4.25 | 5.92 | 0 | 1 | 0 | Appropriate |
| 16:28 | Not good | 29.37 | 4.81 | 6.13 | 0 | 1 | 0 | Appropriate |
| 16:13 | Not good | 29.31 | 4.86 | 6.13 | 0 | 1 | 0 | Appropriate |
| 15:58 | Not good | 29.31 | 4.97 | 6.36 | 0 | 1 | 0 | Appropriate |

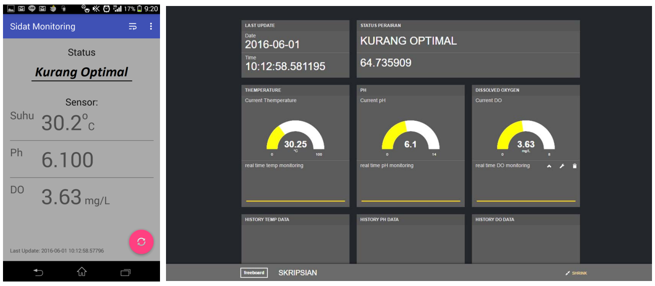


Fig. 9 *Monitoring system visualization*

## VIII. CONCLUSION

The system functions properly with the error reading of the pH sensor is 0.0363, the temperature sensor is 0.0186, while the DO sensor is 0.0923. In our opinion, the unstable voltage problem interferes the system in working properly, especially for the pH meter. However, the fuzzy inference system functions well with 100% accuracy. Moreover, the monitoring system runs well on mobile application as well as on web application.

## REFERENCES


[1] R. A. H. E. Widyasari, “Design integrated development approach for sustainable industry of indonesian eel fish (anguilla spp) in palabuhanratu, sukabumi district, west java province,” Ph.D. dissertation, Dept. Aquaculture., Bogor Agricultural Univ., Bogor, Indonesia, 2013.

[2] O. Rovara, “Reproductive characteristic, masculinization and gonadal maturation of female eel (*Anguilla bicolor bicolor*) with hypophysis extract,” Ph.D. dissertation, Dept. reproductive biology., Bogor Agricultural Univ., Bogor, Indonesia, 2007.

[3] Danish aquaculture development group. (2004, January). Cultured aquatic species information programme anguilla anguilla. FAO. [Online]. Available: http://www.fao.org/fishery/culturedspecies/Anguilla_anguilla/en

[4] R. Affandi, T Budiardi, R. I. Wahtu, A. A. Taurusman, “Eel rearing in water recirculation system,” *JIPI*, vol. 18, no. 1, pp. 55-60, April. 2013

[5] R. Affandi, “[Strategy on Utilization of Eel (*Anguillu sp*.) Resources in Indonesia,” *Jurnal Iktiologi Indonesia*, vol. 5, no. 2, Des. 2005

[6] Sriati, “The study population structure and abundance of seeds eel , Anguilla bicolor , in estuaries Cimandiri , Pelabuhan Ratu , West Java,” M.S. thesis, Dept. Aquatic Sciences., Bogor Agricultural Univ., Bogor, Indonesia, 1998.

[7] M. F. Saaid, N. S. M. Fadhil, M. S. A. M. Ali, M. Z. H. Noor, “Automated indoor aquaponic cultivation technique,” presented at the IEEE 3rd International Conference on System Engineering and Technology, Shah Alam, Malaysia, Aug. 19-20, 2013.

[8] D. Wang, J. Zhao, L. Huang, and D. Xu, “Design of A Smart Monitoring and Control System for Aquaponics Based on OpenWrt,” Proceedings of the 5th International Conference on Information Engineering for Mechanics and Materials, 2015

[9] M Suetake, I. N. D. Silva, A. Goedtel, “Embedded DSP-based compact fuzzy system and its application for induction-motor v/f speed control,” *IEEE Trans Ind Electron*. vol 58, no. 3, pp. 750-760, March. 2011

[10] F. Manenti, F. Rossi, A. G. Goryunov, V. F. Dyadik, K. A. Kozin, I. S. Nadezhdin, S. S. Mikhalevich, “Fuzzy adaptive control system of a non-stationary plant with closed-loop passive identifier,” *Resource-Efficient Technologies*. vol 1, pp. 10-18, Jul. 2015

[11] Fishbase. (2015, January). Fish Identification: Find Species. Fishbase. [Online]. Available: http://www.fishbase.org/identification/SpeciesList.php?genus=Anguilla

[12] M. Negnevitsky, . Artificial Intelligence: A Guide to Intelligent Systems. . Ed ke-2. New York, US: Addison-Wesley, 1993