Tsukamoto fuzzy implementation to identify the pond water quality of koi

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Abstract. The colour quality of koi was affected by the water quality in the pond. Koi fish have a diversity of types differentiated based on the body colour groups, such as one colour pattern, two colour patterns, three colours patterns and even more. Each colour characteristic of the koi have different handling, particularly in the handling of water quality, this is because the colour pigments in the body was affected by the composition of water quality include temperature, pH, TDS, do and salinity. The data of koi fish used were sanke, sowa, kohaku, shiro, yamabuki, ogon and chagoi. The aim of this study is to make an application to inform the condition of the pool water quality that can help breeders to know the water quality that will improve the handling strategies through water media. Tsukamoto Fuzzy method used to produce the three outputs namely water quality, water grade, and water conditions. The output of water quality consists of four categories, namely optimal, moderate, poor, and very poor. The output of water grade consists of grade A to D, while the output of water conditions consist of an excellent, good, bad, and very bad. Input to the application consists of five parameters, namely water temperature, pH, TDS, do and salinity.

1. Introduction
Koi was the most commodity of Indonesian ornamental fish exports. According to statistics the Ministry of Marine Affairs and Fisheries (KKP) Republic of Indonesia 2014, the average ornamental fish total exports was 30%. The quality of the koi that exported should meet several criteria, based on the quality and the sharpness of colour. Each colour characteristic of the koi have different handling, particularly in the handling of water quality, this is because the colour pigments in the body was affected by the composition of water quality include temperature, pH, TDS, do and salinity. Koi have a diversity of types differentiated based on the body colour groups, such as one colour pattern, two colour patterns, three colours patterns and even more. Each colour characteristic of the koi have different handling, particularly in the handling of water quality, this is because the colour pigments in the body was affected by the composition of water quality include temperature, pH, TDS, do and salinity. Water is a factor that support up to 20% to improve the colour quality of the koi besides 70% of quality factor and 10% of other factors (Takeo, 1986) [8]. The previous study as a reference is the determination of the expert system for freshwater fish farming based on the location and quality of water [2]. Research on the use of Tsukamoto Fuzzy method for the determination of water quality aims to determine the condition of the river water with four categories: good condition, lightly polluted, medium polluted and heavy.
polluted [1]. The aim of this study is to make an application to inform the condition of the pool water quality that can help breeders to know the water quality that will improve the handling strategies through water media. Tsukamoto Fuzzy method will produce three outputs namely water quality, water grade, and water conditions. The output of water quality consists of four categories, namely optimal, moderate, poor, and very poor. The output of water grade consists of grade A to D, while the output of water conditions consist of an excellent, good, bad, and very bad. Input to the application consists of five parameters, namely water temperature, pH, TDS, do and salinity.

2. Methodology
The research methodology used to identify water quality of Koi using an expert system approach [6] with Tsukamoto fuzzy method [3] through several stages as shown in Figure 1.

![Figure 1. Stages of Fuzzy Tsukamoto.](image)

The optimal water quality can improve and boost the quality of Koi, while poor water quality can resulting in decreased quality of Koi. Data types of water used in this study is a kind of water for Koi species by colour pattern, namely the Koi one colour, two colours, three colours and mix. These fishes are Sanke, Sowa, Kohaku, Shiro, Ogon, Yamabuki, and mix. All four categories of Koi have different needs and characteristics almost the same but different. The parameters used are water parameters that independent from each other and influence on the quality of Koi. Water parameters include temperature, pH, TDS (solute in the water), do (dissolved oxygen) and salinity (salt content) [5] [7]. The tools needed to measure the parameters of water can use the pH meter tools, TDS meter, DO meter, Salinity meter, and Thermometer. Objects were observed in this study is the quality of water by reference to the type of water used by Koi champion [4] and ordinary koi pet, by categorized into several qualities include: Optimal (A), Moderate (B), Poor (C) and Very Poor (D). Data of Koi fish pond water quality shown in Table 1.

2.1 Fuzzification process
Fuzzification was done to divide the variables into fuzzy sets that will be used in making the rules. Water parameters were developed on the basis of fuzzy system that uses a Fuzzy Inference System (FIS) as a process to determine the final results as shown in Table 2.
### Table 1. Water quality of Koi pond

| Koi Type | Water Parameter | Unit | [A] Optimal | [B] Moderate | [C] Poor | [D] Very Poor |
|----------|----------------|------|-------------|-------------|---------|-------------|
| Mix      | Temperature    | Celsius | 23-25 | 20-28 | 15-20 ; 28-30 | <=10 ; >=32 |
|          | pH             | Ph    | 7.2 – 7.5 | 7.0 -7.8 | 5.5-6.5 ; 8.0 -8.5 | 0 - 4.0 ; >8.5 |
|          | TDS            | Ppm   | 20-80 | 0-150 | 200-300 | >400 |
|          | DO             | Ppm   | >7.0 | 5.0 – 6.0 | 3.0-4.0 | < 2 |
|          | Salinity       | Ppm   | 0.05-0.15 | 0.00-0.2 | 0.25 - 0.3 | >0.4 |
| Chagoi   | Temperature    | Celsius | 25-29 | 20-30 | 15-20 ; 30-32 | <=10 ; >=35 |
|          | pH             | pH    | 7.5 – 8.5 | 7.0 -8.7 | 5.5-7 ; 8.7-8.8 | 0 - 5.0 ; >9 |
|          | TDS            | Ppm   | 75-100 | 0-150 | 200-300 | >400 |
|          | DO             | Ppm   | >7.0 | 5.0 – 6.0 | 3.0-4.0 | < 2 |
|          | Salinity       | Ppm   | 0.05-0.15 | 0.00-0.2 | 0.25 - 0.3 | >0.4 |
| Ogon     | Temperature    | Celsius | 18-22 | 15-28 | 13-15; 28-30 | <=10 ; >=32 |
|          | pH             | pH    | 7.5 – 8.5 | 7.0 -8.7 | 5.5-7 ; 8.7-8.9 | 0 - 5.0 ; >9 |
|          | TDS            | Ppm   | 300-350 | 0-400 | 450-500 | >550 |
|          | DO             | Ppm   | >7.0 | 5.0 – 6.0 | 3.0-4.0 | < 2 |
|          | Salinity       | Ppm   | 0.05-0.15 | 0.00-0.2 | 0.25 - 0.3 | >0.4 |
| Yamabuki | Temperature    | Celsius | 25-26 | 20-28 | 15-20 ; 28-30 | <=10 ; >=32 |
|          | pH             | pH    | 6.8 – 7.4 | 6.5--; 7.5 | 5.5-6.5 ; 7.5-8.0 | 0 - 5.0 ; >8.5 |
|          | TDS            | ppm   | 250-300 | 0-350 | 400-450 | >500 |
|          | DO             | ppm   | >7.0 | 5.0 – 6.0 | 3.0-4.0 | < 2 |
|          | Salinity       | ppm   | 0.05-0.15 | 0.00-0.2 | 0.25 - 0.3 | >0.4 |
| Shiro    | Temperature    | Celsius | 25-28 | 20-30 | 15-20 ; 30-32 | <=10 ; >=35 |
|          | pH             | pH    | 7.5 – 8.5 | 7.0 -8.7 | 5.5-7 ; 8.7-8.9 | 0 - 5.0 ; >9 |
|          | TDS            | ppm   | 75-100 | 0-150 | 200-300 | >400 |
|          | DO             | ppm   | >7.0 | 5.0 – 6.0 | 3.0-4.0 | < 2 |
|          | Salinity       | ppm   | 0.05-0.15 | 0.00-0.2 | 0.25 - 0.3 | >0.4 |
| Showa    | Temperature    | Celsius | 25-26 | 20-28 | 15-20 ; 28-30 | <=10 ; >=32 |
|          | pH             | pH    | 6.8 – 7.4 | 6.5--; 7.5 | 5.5-6.5 ; 7.5-8.0 | 0 - 5.0 ; >8.5 |
|          | TDS            | ppm   | 250-300 | 0-350 | 400-450 | >500 |
|          | DO             | ppm   | >7.0 | 5.0 – 6.0 | 3.0-4.0 | < 2 |
|          | Salinity       | ppm   | 0.05-0.15 | 0.00-0.2 | 0.25 - 0.3 | >0.4 |
| Sanke    | Temperature    | Celsius | 25-28 | 20-30 | 15-20 ; 30-32 | <=10 ; >=35 |
|          | pH             | pH    | 7.5 – 8.5 | 7.0 -8.7 | 5.5-7 ; 8.7-8.9 | 0 - 5.0 ; >9 |
|          | TDS            | ppm   | 75-100 | 0-150 | 200-300 | >400 |
|          | DO             | ppm   | >7.0 | 5.0 – 6.0 | 3.0-4.0 | < 2 |
|          | Salinity       | ppm   | 0.05-0.15 | 0.00-0.2 | 0.25 - 0.3 | >0.4 |

### Table 2. Water parameter

| Input Parameter | Unit Value | Fuzzy |
|-----------------|------------|-------|
| Temperature     | Celsius    | Fuzzy |
| pH              | Acid (< 7), normal (7), base (> 7) | Fuzzy |
| TDS             | ppm        | Fuzzy |
| DO              | ppm        | Fuzzy |
| Salinity        | ppt        | Fuzzy |

2.2 Membership function

Membership functions were used to assign values to fuzzy set and domain for each water quality parameters, as shown in Table 3.

2.3 Membership function of water quality output

Output identification of water quality represented by the triangle curve shown in Figure 2. The output value rated 100 to 500, scoring of 100 to 500 was to determine the range of each output, so it can be classified on the calculation result of water quality output was optimal (A), moderate (B), poor (C), or very poor (D) as shown in Table 4.
Table 3. The fuzzy set and water parameter domain

| Parameter | Fuzzy set | Domain                      |
|-----------|-----------|-----------------------------|
| Temperature | Excellent | [22.5 25 26 27]             |
|           | Good      | [17.5 20 22.5 25], [26 27 28 29] |
|           | Bad       | [12.5 15 17.5 20], [28 29 30 31] |
|           | Very Bad  | [0 10 12.5 15], [30 31 32 32] |
| Ph        | Excellent | [6.65 6.8 7.4 7.7]          |
|           | Good      | [6 6.5 6.65 6.8], [7.4 7.7 8 8.2] |
|           | Bad       | [6.25 5.5 6 6.5], [8 8.25 8.5 8.6] |
|           | Very Bad  | [0 0 5.25 5.5], [30 31 32 32] |
| TDS       | Excellent | [125 250 300 325]           |
|           | Good      | [0 0 125 250], [300 325 350 400] |
|           | Bad       | [350 400 450 475]           |
|           | Very Bad  | [450 475 500 500]           |
| d.o       | Excellent | [6 7 7 7]                   |
|           | Good      | [4 5 6 7]                   |
|           | Bad       | [3 3.5 4 5]                |
|           | Very Bad  | [0 0 3 3.5]                |
| Salinity  | Excellent | [0.025 0.05 0.15 0.175]     |
|           | Good      | [0.15 0.175 0.2 0.225]      |
|           | Bad       | [0.2 0.225 0.3 0.35]        |
|           | Very Bad  | [0.3 0.35 0.4 0.4]         |

Figure 2. Membership function output of water quality

Table 4. Fuzzy set and output parameter domain

| Parameter (water quality) | Fuzzy set  | Domain          |
|---------------------------|-------------|-----------------|
| Output                    | Optimal (A) | [0 100 200]     |
|                           | Moderate (B)| [100 200 300]   |
|                           | Poor (C)    | [200 300 400]   |
|                           | Very Poor (D)| [300 400 500] |

2.4 Making Rules and Fuzzy Reasoning

The rules applied represented in form “if-then” rules and connect between the premises with the operator "and" while the degree of membership selected on each parameter was the biggest value because using the operator "or". The fuzzy reasoning method based on an evaluation of each rule before it can be concluded (defuzzification), at this stage the degree of membership value parameter of water that has been sought to be used as input information of each rule that was created, of course, the rule used was the rule that only has the relationship between the
fuzzy membership with the rule. Then, this process will produce output values based on the output membership function of each rule. The rule made was two rules that have relationship as the following example:

[R1] IF temperature quality EXCELLENT AND ph quality EXCELLENT AND TDS quality GOOD AND DO quality EXCELLENT AND Salinity quality GOOD THEN pond water quality is Grade B

\[
\alpha_1 = \mu_{\text{temperature EXCELLENT}}(\text{temperature}) \cap \mu_{\text{ph EXCELLENT}}(\text{ph}) \cap \mu_{\text{tds GOOD}}(\text{tds}) \cap \mu_{\text{do EXCELLENT}}(\text{do}) \cap \mu_{\text{salinity GOOD}}(\text{salinity}) \\
= \text{Min} (\mu_{\text{temperature EXCELLENT}}(25.5), \mu_{\text{ph EXCELLENT}}(7.4), \mu_{\text{tds GOOD}}(93), \mu_{\text{do EXCELLENT}}(8.4), \mu_{\text{salinity GOOD}}(0.00)) \\
= \text{Min} (0.52, 1, 1, 1) \\
= 0.52
\]

Based on the water quality set Grade B, then:

\[
\mu gB = \frac{(300 - x)}{(300 - 200)} \\
Z_1 = 300 - (0.52 \times (300 - 200)) = 248
\]

[R2] IF temperature quality GOOD AND ph quality EXCELLENT AND TDS quality GOOD AND DO quality EXCELLENT AND Salinity quality GOOD THEN pond water quality is grade B

\[
\alpha_2 = \mu_{\text{temperature GOOD}}(\text{temperature}) \cap \mu_{\text{ph EXCELLENT}}(\text{ph}) \cap \mu_{\text{tds GOOD}}(\text{tds}) \cap \mu_{\text{do GOOD}}(\text{do}) \cap \mu_{\text{salinity GOOD}}(\text{salinity}) \\
= \text{Min} (\mu_{\text{temperature GOOD}}(25.5), \mu_{\text{ph EXCELLENT}}(7.4), \mu_{\text{tds GOOD}}(93), \mu_{\text{do EXCELLENT}}(8.4), \mu_{\text{salinity GOOD}}(0.00)) \\
= \text{Min} (0.48, 1, 1, 1) \\
= 0.48
\]

Based on the water quality set Grade B, then:

\[
\mu gB = \frac{(300 - x)}{(300 - 200)} \\
Z_2 = 300 - (0.48 \times (300 - 200)) = 252
\]

2.5 Defuzzification
The output process marked by defuzzification stage to produce a crisp values of some output fuzzy rule evaluation results to the knowledge base. Defuzzification method used in this study was the weighted average method, these results will be used as criteria to assess water quality, crisp values obtained as in equation (1).

\[
Z = \frac{(\alpha_1 \times z_1) + (\alpha_2 \times z_2) + \cdots + (\alpha_n \times z_n)}{\alpha_1 + \alpha_2 + \cdots + \alpha_n}
\] (1)

The final result based on sample of test data by using equation (1) then,

\[
Z = \frac{(248\times 0.52) + (252\times 0.48)}{0.52 + 0.48} = 249.92
\]

Based on the Tsukamoto fuzzy values obtained = 249.92, because it is in the range between 200 and 300 then this value is categorized as Grade B, Moderate types of water quality.

2.6 Validation Test of Water Quality System Assessment on Expert
The testing process carried out on 21 test data to ensure the compatibility between the systems and expert. The test results by grouping types of Koi fish are shown in Table 5.
### Table 5. Testing result of water quality system between the output system and expert

| Koi Pond type | temperature (°C) | pH | TDS (ppm) | d.o. (ppm) | Salinity (ppt) | Tsukamoto value | Water quality (Grade) | Expert validation |
|---------------|------------------|----|-----------|------------|---------------|-----------------|----------------------|-------------------|
| Mixed         | 26.3             | 7.54| 74        | 8.2        | 0.11          | 238.59          | B                    | Valid             |
| Mixed         | 23.7             | 7.5 | 87        | 7.2        | 0.16          | 185.71          | A                    | Valid             |
| Mixed         | 28.7             | 7.1 | 146       | 4.2        | 0.16          | 347.5           | C                    | Valid             |
| Mixed         | 32.7             | 6.1 | 354       | 4.2        | 0.16          | 457.14          | D                    | Valid             |
| Mixed         | 24.2             | 7.3 | 67        | 7          | 0.16          | 148             | A                    | Valid             |
| Kohaku        | 28.2             | 7.7 | 105       | 8.9        | 0.15          | 188.57          | A                    | Valid             |
| Kohaku        | 24.2             | 7.3 | 67        | 7          | 0.16          | 260.26          | B                    | Valid             |
| Kohaku        | 24.2             | 6.3 | 164       | 4          | 0.16          | 367.38          | C                    | Valid             |
| Kohaku        | 32.2             | 8.9 | 209       | 7          | 0             | 418.24          | D                    | Valid             |
| Sanke         | 23.8             | 7.4 | 93        | 8.4        | 0             | 249.92          | B                    | Valid             |
| Sanke         | 28.2             | 7.9 | 209       | 7          | 0             | 334.226         | C                    | Valid             |
| Sowa          | 32.2             | 8.9 | 209       | 7          | 0             | 444.08          | D                    | Valid             |
| Sowa          | 25.2             | 7.4 | 239       | 7          | 0             | 124.85          | A                    | Valid             |
| Shiro         | 28.2             | 7.7 | 105       | 8.9        | 0.15          | 252             | B                    | Valid             |
| Shiro         | 22              | 7.5 | 249       | 7          | 0.15          | 178.88          | A                    | Valid             |
| Shiro         | 29              | 7.5 | 456       | 5          | 0.15          | 249.28          | C                    | Valid             |
| Shiro         | 29              | 6.7 | 590       | 4          | 0.2           | 448             | D                    | Valid             |
| Ogon          | 23.7             | 8.1 | 110       | 7.2        | 0.16          | 231.13          | B                    | Valid             |
| Ogon          | 29              | 6.7 | 590       | 4          | 0.2           | 448             | D                    | Valid             |
| Yamabuki      | 27.5             | 7.4 | 87        | 6          | 0.1           | 140             | A                    | Valid             |
| Yamabuki      | 25.2             | 7.8 | 356       | 4          | 0             | 400             | C                    | Valid             |

Based on Table 5, the precision accuracy can be calculated using the Confusion Matrix, by comparing the 21 test data to classified water quality grade A (+) and grade BCD (-). The final result was shown in Table 6 with the accuracy up to 100%.

### Table 6. The Final Result

| Testing Expert (Actual) | Negative | Positive |
|-------------------------|----------|----------|
| Fuzzy Tsukamoto (Predict) |          |          |
| Negative                | 15       | 0        |
| Positive                | 0        | 6        |

### 3. Conclusion

Research on the application of Fuzzy Tsukamoto for the identification of Koi water quality pond aims to create a system that can assess the quality of water in four criteria, ie optimal (grade A), moderate (grade B), poor (grade C), and very poor (grade D). The quality of water was determined based on five parameters: temperature, pH, Tds, Do Kyung-soo and salinity. The method used was the development of expert systems with Tsukamoto Fuzzy application.
The testing process carried out on 21 test data of Koi species based on colour pattern namely Koi one colour, two colours, three colours and mix. The koi species was Sanke, Sowa, Kohaku, Shiro, Ogon, Yamabuki and mix. The test result compared the calculation of the system and expert assessment, which produced an accuracy of 100%.

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