Philosophy of Fuzzy Logic as Fundamental of Decision Making Based On Rule

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Abstract. The logic of talking about rules of thought so that these rules can draw correct conclusions, but in reality in everyday life many things are found that cannot be stated that something is absolutely true or absolutely false. This study aims to explain that the philosophy of fuzzy logic is the basis for decision making based on IF-THEN rules. Related to the role of philosophy of science as the basis for the development of fuzzy logic, it cannot be separated from ontology, epistemology and axiology. The findings of this study are Ontology covering decision making and rules for decision making. Decision making is an election based on certain criteria for two or more possible alternatives while decision making rules are fuzzy rules in the form of IF-THEN. While epistemology of fuzzy logic is related to how the process to get output, how are the stages to take decisions. The process of getting output consists of fuzzification and inference. The output obtained by the value of Z * 38541.67 and the rule-based fuzzy logic axiology in giving restaurant waiter tips is useful to be able to determine the total cash of tips that will be given to the restaurant waiter. The total cash of appropriate tips given based on service and food to the restaurant waiter is Rp.38.541.

1. Introduction
Philosophy is the science that finds out the solutions to problems posed by other positive sciences, and finds out the meeting point to meet all the other sciences. According to Cicero (106–043 BC), "Philosophy is the mother of all other sciences. Philosophy is the science of the ancestors and the desire to obtain it. The word philosophy came from the Greek "philosophia" from the word "philos" meant love and "Sophia" meant wise knowledge. The emergence of philosophy in the 5th century BC was a breakdown of the myth era at that time. There was a revolution of thought towards the age domination of myths over the truth claims. This period was an important period when reason started being used in an effort to find truth, reason as a means of searching for truth, reason as a source of truth. The history of thought entered a new era that was Logos era. Philosophy is said to be the mother of science. In its development philosophy emerged branches of science, which developed into small branches of science, sub-branches of science. In its development, science has increased more specifically and technically which moved individually that did not keep in touch one each other. In its development, a lot of fundamental problems emerged which caused science to be farther from its
essence. Philosophy has two meanings: First philosophy is as a product: it implies that philosophy as a type of science, concepts, theories, flow systems which are the result of philosophical processes. On the second, philosophy is as a process; in this case philosophy is defined as a form of philosophical activity as a process of problem solving using certain methods and methods [1]. As a science, philosophy is science with material objects are: the "There" includes humans, nature, God (anthropos, cosmos, Theos) along with the problems inside it, while the formal object of philosophy is to examine its material objects deeply until found the essence / the main problem. Not all activities of thinking as an activity of philosophizing. The activity of thinking philosophically (in sense as) of science has the following characteristics: Radical Critic - Conceptual - Coherent - Speculative Rational - Systematic - Comprehensive – Universal Free [2].

In addition, philosophy has developed into special science; in itself, philosophy has branches that continuing to develop in accordance with the development of the problems to be handled. The main branches of philosophy are: Ontology-Epistemology-Logic-Ethics-Aesthetics. These branches of philosophy are the first circle, then there are still second circle such as: social philosophy, political philosophy, philosophy of law, philosophy of economics, philosophy of religion, and the third circle such as: philosophy of science, philosophy of culture, philosophy of language, philosophy of environment [3].

2. Theory

2.1 Logical Philosophy
Logic is a branch of practical philosophy. Here, practical means that logic can be applied in daily life. Logic was born together with the birth of philosophy in Greece. Logic examined the principles of true reasoning and valid conclusion reasoning. This science was first developed around 300 BC by Aristotle and known as traditional logic or classical logic. Two thousand years later, modern logic was developed by George Boole and De Morgan which called Symbolic Logic because it used logic symbols intensively [4].

In an effort to broaden their thoughts and opinions, the ancient Greek philosophers often tried to refute other thoughts by showing the error of their reasoning. Logic was used to do proof. Logic told which forms of inference were valid and non-valid. Traditionally, logic was studied as a branch of philosophy, but it could be also considered as a branch of mathematics. Logic as a branch of philosophy was a branch of philosophy about thoughts. Logic talked about rules of thinking so that these rules could draw the correct conclusions. By knowing the way or the rules could avoid mistakes in making decisions. According to Louis O. Kattsoff (1987), logic talks about techniques to obtain conclusions from a particular set of materials and sometimes logic is defined as the science of drawing conclusions [3].

The basic of logic reasoning is true and false logic which is symbolized by 0 and 1 which is also called with Binary Logic. But, in fact in daily life, there are many things that we encounter that cannot be stated whether it is absolutely true or absolutely false. To overcome the problems which occurred in classical logic developed by Aristotle, a scientist from the University of California Berkeley, Prof Lotfi A Zadeh in 1965 introduced a new concept of logical thinking, Fuzzy Logic [3].

2.2 Fuzzy Logic
In general, fuzzy logic is a method of "counting" with a linguistic variable, instead of counting with numbers. With fuzzy logic, the human expertise system can be implemented into machine language. Fuzzy logic allows membership values to be between 0 and 1, gray level and also black and white, and in linguistic form, this uncertain concepts such as "little", "decent", “very”. There are several reasons why using fuzzy logic: The concept of fuzzy logic is so simple that it is easy to understand, namely in the naturalness of its approach to solve problems, Flexible, in this sense that it can be built and
developed easily. Be able to tolerate data uncertainty, Modelling/mapping to find out the relationship of input – output data from any system which can be done by applying fuzzy. Knowledge or experience from experts can be used easily to build fuzzy logic without going through the training process. Fuzzy logic can work with control techniques conventionally, Fuzzy logic is based on natural language or human language [4].

With fuzzy logic, the human expertise system can be implemented into machine language easily and efficiently. The main motivation for the theory of fuzzy logic is mapping an input space into the output space using IF-THEN rules. Mapping is done in a Fuzzy Inference System (FIS). Fuzzy Inference System (FIS) or Fuzzy Inference Engine is a system that can do reasoning with the same principle as humans doing reasoning with their instincts (Alavi, et al., 2010). The first step of FIS is to establish membership values for input and output data (Alidoosti, et al., 2012) [4]. According to Kusumadewi & Hartati (2010), fuzzy inference system is a computational framework based on theory of fuzzy set, fuzzy rules in the form of IF-THEN, and fuzzy reasoning. In outline, the block diagram of defuzzy inference process is shown in Figure 1 below [5].

![Figure 1. Block Diagram of Fuzzy Inference Systems (Kusumadewi & Hartati, 2010).](image)

2.3 Decision Support System Rule Based

Decision Support System is a system that provides the ability to solve problems and communication for semi-structured problems [6]. Turban categorized the Decision Making System into seven models. One of the seven models which is quite popular, is Fuzzy Inference System (FIS). Before building FIS, all rules or rules must be defined first before being used to interpret the rule. There are several known types of FIS, namely Mamdani, Sugeno and Tsukamoto (Naba, 2009) [7]. The Mamdani method is usually known as the Max-Min method. This method was introduced by Ebrahim Mamdani in 1975. To get output, four steps are needed:

1. Formation of fuzzy sets in Mamdani Method, both input variables and output variables are divided into one or more fuzzy sets
2. Application of implication function in Mamdani method, the implication function used is min.
3. Composition of Inference rule is being obtained from a collection and correlation between rules. There are 3 kinds of rules Max, Additive, and probabilistic OR (probor)
4. Affirmation (defuzzycation) Input here is a set of fuzzy obtained from the composition of fuzzy rules. The output is a strict value (Crips). Defuzzyfication method: Centroid (Center of Mass), and Mean of Maximum (MOM) [8].

3. Discussion

Applying the philosophy of science as a starting point allows us to explore various philosophies of knowledge including the philosophy of logic. Philosophy here is about knowledge of logic. The substance of logic is true and false logic. But in fact in daily life
there are many things that we encounter that cannot be stated that it is absolutely true or absolutely false. Logic talks about rules of thought so that these rules can draw correct conclusions. By knowing the way or the rules can avoid mistakes in making decisions. Related to the role of philosophy of science as the basis for the development of fuzzy logic, it cannot be separated from its parent study, namely ontology, epistemology and axiology.

3.1 Ontology
Ontology relates to what objects are examined by fuzzy logic, in this study includes decision making and rules of decision making. Decision making is an election based on certain criteria for two or more possible alternatives, while decision making rules are fuzzy rules in the form of IF-THEN. Case examples of determining tips for servants of a restaurant, if service = 7 and food = 8; and the range of tips is Rp. 10,000, up to Rp. 50,000. Dinner for two-input, one-output and three-rule problems. Two inputs: services with a range of values (0-10), food with a range of values (0-10). With three rule problems:
1. Rule 1: IF service is poor OR food is rancid, THEN tip is cheap
2. Rule 2: IF service is good, THEN tip is average
3. Rule 3: IF service is excellent OR food is delicious, THEN tips is generous

3.2 Epistemology
Epistemology is seen as synonymous with fuzzy logic theory. At present the theory of fuzzy logic cannot be ignored. Epistemology of fuzzy logic is related to how the process to get output, how the stages to make decisions. Problems in the philosophy of logic science basically shows the topics of study that can enter into one of the philosophical scopes of fuzzy logic. The problems are: Fuzzification, Inference.

Fuzzification is changing inputs whose truth values are definite (crisp input) in the form of fuzzy input, in the form of linguistic values whose semantics are determined based on certain membership functions and inference is to reason using fuzzy input and fuzzy rules that have been determined to produce fuzzy output. In syntax a fuzzy rule is written as follows: IF antecedent THEN consequen.

The steps in the process of getting the output of restaurant waiter tips are as follows:
1. Determine linguistic variables and linguistic values

| Variable | Variable Linguistic | Linguistic Value |
|----------|---------------------|------------------|
| Service  | Poor                | 0 – 4            |
|          | Good                | 2 – 8            |
|          | Excellent           | 6 – 10           |
|          | Rancid              | 0 – 6            |
| Food     | Delicious           | 4 – 10           |
|          | Cheap               | 10 – 30          |
| Tips     | Average             | 20 – 40          |
|          | Generous            | 30 – 50          |

2. Determine the Variable Functions and Membership Functions of each variable
Figure 2. Graph of Service Functions.

Membership function Service Variable:

\[
\mu_{\text{service poor}}(x) = \begin{cases} 
    1, & x \leq 2 \\
    \frac{4-x}{2}, & 2 \leq x \leq 4 \\
    0, & x \geq 4 
\end{cases} \\
\mu_{\text{service good}}(x) = \begin{cases} 
    0, & x \leq 2, x \geq 8 \\
    \frac{x-2}{2}, & 2 \leq x \leq 4 \\
    \frac{8-x}{2}, & 6 \leq x \leq 8 
\end{cases} \\
\mu_{\text{service Excellent}}(x) = \begin{cases} 
    0, & x \leq 6 \\
    \frac{x-6}{2}, & 6 \leq x \leq 8 \\
    1, & x \geq 8 
\end{cases}
\]

Figure 3. Graph of Food Function.

Membership function Food Variable:

\[
\mu_{\text{Food Rancid}}(y) = \begin{cases} 
    1, & y \leq 3 \\
    \frac{6-y}{3}, & 3 \leq y \leq 6 \\
    0, & x \geq 6 
\end{cases}
\]
Figure 4. Graph of the Tips function.

Membership function Tip Variable:

\[ \mu_{\text{Tips Cheap}} (z) = \begin{cases} 
1, & z \leq 20 \\
\frac{30 - z}{10}, & 20 \leq z \leq 30 \\
0, & z \geq 30 
\end{cases} \]

\[ \mu_{\text{Tips Average}} (z) = \begin{cases} 
0, & z \leq 20, z \geq 40 \\
\frac{z - 20}{10}, & 20 \leq z \leq 30 \\
\frac{40 - z}{10}, & 30 \leq z \leq 40 
\end{cases} \]

\[ \mu_{\text{Tips Generous}} (z) = \begin{cases} 
0, & z \leq 20 \\
\frac{z - 30}{10}, & 30 \leq z \leq 40 \\
1, & z \geq 40 
\end{cases} \]

3. Fuzzification

| Variabel Service | Variabel Food |
|------------------|---------------|
| \( \mu_{\text{service poor}} (7) = 0 \) | \( \mu_{\text{food rancid}} (8) = 0 \) |
| \( \mu_{\text{service good}} (7) = \frac{8 - 7}{2} = \frac{1}{2} = 0.5 \) | \( \mu_{\text{food delicious}} (8) = 1 \) |
| \( \mu_{\text{service excellent}} (7) = \frac{7 - 6}{2} = \frac{1}{2} = 0.5 \) | |

4. Implication

Rule 1: IF service is poor OR food is rancid, THEN tips is cheap

\( \alpha \text{ predikat} = \mu_{\text{service poor}} \cup \mu_{\text{food rancid}} \)

\( = \max \left[ \mu_{\text{service poor}} (7), \mu_{\text{food rancid}} (8) \right] \)

\( = \max \left[ 0, 0 \right] \)
= 0

**Figure 5.** Graph of Rule Implications 1.

Rule 2: IF service is *good*, THEN tips is *average*
\[ \alpha_{\text{predikat}} = \mu_{\text{service good}} = 0.5 \]

**Figure 6.** Graph of Rule Implications 2.

Rule 3: IF service is *excellent* OR food is delicious, THEN tips is generous
\[ \alpha_{\text{predikat}} = \max [\mu_{\text{service excellent}}, \mu_{\text{food delicious}}] = \max [0.5, 1] = 1 \]

**Figure 7.** Graph of Rule Implications 3.

5. Aggregation
Figure 8. Graph of Aggregation Functions.

| Point | Value |
|-------|-------|
| Z₁    | 20    |
| Z₂    | 25    |
| Z₃    | 35    |
| Z₄    | 40    |
| Z₅    | 50    |

\[ Z₂ \text{ points are obtained by means of:} \]
\[ 0.5 = \frac{z₂ - 20}{10} \]
\[ z₂ - 20 = 5 \]
\[ z₂ = 25 \]

\[ Z₃ \text{ points are obtained by means of:} \]
\[ 0.5 = \frac{z₃ - 30}{10} \]
\[ z₃ - 30 = 5 \]
\[ z₃ = 35 \]

6. Defuzzification

\[ Z^* = \frac{\int_a^b \mu_A(z) \cdot z \, dz}{\int_a^b \mu_A(z) \, dz} \]

\[ Z^* = \frac{\int_{20}^{25} \left( z - \frac{20}{10} \right) z \, dz + \int_{25}^{35} \left( 0.5 \right) z \, dz + \int_{35}^{40} \left( z - \frac{30}{10} \right) z \, dz + \int_{40}^{50} z \, dz}{\int_{20}^{25} \left( z - \frac{20}{10} \right) \, dz + \int_{25}^{35} \left( 0.5 \right) \, dz + \int_{35}^{40} \left( z - \frac{30}{10} \right) \, dz + \int_{40}^{50} 1 \, dz} \]

\[ Z^* = \frac{770.833.333.3}{20.000} \]

\[ Z^* = 38541.67 \]

3.3 Axiology

Axiology is science that investigates the nature of values viewed from the philosophical angle. The basis for the level of axiology is for what knowledge is used? How is the relationship between scientific use and moral ethics? How is the determination of objects studied morally? What is the connection between scientific procedures and scientific methods with moral rules.

Likewise the rule-based fuzzy logic axiology of giving tips to employees of a restaurant is useful in determining the number of tips given to the restaurant waiter. Based on the steps to get the output of giving tips, the value of \( Z^* \) was obtained at 38541.67. The \( Z^* \) value is useful in terms of determining the number of tips to be given to the restaurant waiter based on service and food conditions. The number of tips that will be given is Rp. 38,541.

4. Conclusion

1. Philosophy is the science that seeks solutions to problems posed by other positive sciences, and seeks to meet all other sciences
2. Science is inseparable from the foundation of ontology, epistemology and axiology
3. Ontology in this study covers decision making and rules for decision making. Decision making is an election based on certain criteria for two or more possible alternatives while decision making rules are fuzzy rules in the form of IF-THEN

4. Epistemology of fuzzy logic is related to how the process to get output, how the stages to make decisions. The process of getting output consists of fuzzyfication and inference. The output obtained by the value of $Z$ is 38541.67

5. The rule-based fuzzy logic axiom of giving tips to employees of a restaurant is useful in determining the number of tips that will be given to the restaurant waiter. The number of appropriate tips given based on service and food to the restaurant waiter is Rp. Rp. 38,541

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