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Implementation of the sugeno fuzzy logic method in identifying the quality of coffee beans

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Abstract. Identifying the quality of coffee beans is quite important to be followed up better because it involves the products to be processed or traded. Because the management is quite a lot and complicated, it is proposed to design an application for identifying the quality of coffee beans. With these demands, it is necessary to measure the quality of coffee beans by using Sugeno's Fuzzy Logic method. The identification of the quality of coffee beans using Fuzzy Sugeno by using the Sugeno Fuzzy model of the zero order and using the rule as much as 36, which is in accordance with the need to support the conclusions of quality from the identification results.

1. Introduction

North Sumatra Province is wrong as a coffee-producing region in Indonesia and also as a country producing and producing the largest coffee in the world. The type of coffee that is famous for its aroma is typically Arabica coffee or in the language of the surrounding area called *"Sigarar Utang"*(read pay debts). Coffee lovers can distinguish the quality of taste and acidity after processing. This problem is influenced by natural factors such as the fields / land where coffee is planted, such as the type of land construction, soil height from sea level, composition of coffee plants, and the process of coffee cultivation itself.

The quality aspect is an important thing in the world coffee bean trade. So far there have been many studies on the topic of seed coffee quality such as Charley and Weafeer (1998) and have mapped the quality of coffee in the world market, Gonzales Rios et al (2007) relate aspects of coffee quality and handling after harvest. Alejandro and Morales (2002) examined coffee on grading system problems. According to SNI 01-2907-2008, the classification of the quality of coffee beans was viewed from the level of defective values, including normal coffee beans, black broken seeds coffee, spotted coffee beans, holes> 1 , charred coffee beans and skin damage / physical defects such as the shape of the stone, the color of the soil, twigs and gravel [1].

Coffee is a type of beverage for all groups that comes from the processing and the extraction and extraction of coffee bean seeds. The history of coffee has been recorded since the 9th century. For the first time, coffee only exists in Ethiopia, where native coffee beans are planted by upland Ethiopians. At that time, many people in the African continent, especially the Ethiopians, consumed coffee beans by mixing animal fat and wine to meet the

body's protein and energy needs. However, when the Arabs expanded the coffee trade, coffee beans also continued to expand to the North African continent, coffee beans in this country were planted in bulk. From North Africa coffee beans began to spread widely to Asia until they captured the European market and fame as a favorite beverage and continued to spread [1]. This coffee drink continues to grow until now it is one of the most popular drinks in the world that is consumed by all elements in the community. Indonesia has also succeeded in producing up to 400 thousand tons of coffee every year. Indonesia in the era of the 1990s was the third largest coffee exporter in the world after Brazil and Columbia.

The Latin name of coffee has a name is *Coffea*. Coffee beans are divided into 5 parts, namely the outer skin layer of coffee (exocarp), coffee fruit flesh (mesocarp), horn skin (parchment), epidermis and coffee beans (endosperm) [2].

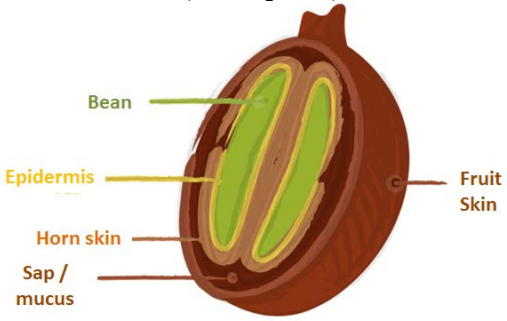

Figure 1. Coffee Bean Parts

The skin of coffee fruit is very thin and contains chlorophyll and other dyes. Meat or coffee fruit consists of 2 parts, the outer part is thicker and harder and the inside is like a gel or mucus. In this mucus layer, there is a water content of up to 85% in the bound form, and a colloidal material of 15% which does not contain water [3]. This part is a hydrophilic colloid which consists of ± 80% pectin and ± 20% sugar. The fruit portion is located between the flesh of the fruit with seeds (endosperm) called horn skin.

Sugeno fuzzy method is one of the best research techniques because of its reliability in bridging system or machine language which has precision related to human language which is always not precise, namely by focusing on meaning or significance. It is conceivable that fuzzy Sugeno is a machine that converts / translates from human language to machine language and vice versa until it can be understood by the system and humans. The aim of the study was to analyze and test and apply Sugeno's fuzzy method as a quality decision making technique and expert in the process of identifying the quality of coffee beans, becoming an important part of the strategy of developing coffee agroindustry [4][5].

2. Research Methods

The research method used in making this application is the System Development Life Cycle (SDLC). The SDLC method is a series of activities carried out by professionals and users of information systems to develop and implement applications [6] [7]. The complete stages of the SDLC approach are as follows:

1. System Planning Phase At the planning stage data collection is carried out and determine how the system can help solve existing problems. This planning stage is carried out based on:
   a. Observation In this study research data was taken from field research and library research.

   b. Interview. The interview was conducted directly with the lecturer and dean of the Faculty of Computer Science regarding the criteria related to the subject matter of the study.
   c. Library Studies. Collection of materials that are related to the discussion in the study.
2. Phase Analysis This analysis phase is carried out by analyzing the system needed to determine the criteria for selecting teaching assistants, namely: Data Analysis, Problem Identification, System Analysis
3. Design Phase. The system design phase is carried out through 2 stages, namely: 1). Database Designing In this design is done by making a table structure and data related to the database. 2). General System Design In this stage a plan is carried out in a system workflow procedure that will be described by a data flow diagram and a Flowchart system.
4. Implementation Phase. The system implementation phase is a process that is carried out after the design phase is completed, after which it makes the manufacturing stage into the programming language. The programming languages used are PHP and HTML while MySQL is the database [8].
5. Trial Phase. System testing is a test that is carried out after the making of the system is completed by conducting an experiment on the user interface. Following are some of the tests performed on the system made.
   a. Structural Trial Structural trials are tests conducted to determine whether the system built by the structure or program flow is in accordance with the design.
   b. Functional Tests Functional trials are tests carried out to determine whether the system is functioning properly or not.
   c. Validation Test Validation trials are tests that are conducted to determine the level of accuracy between manual calculations with calculations on the system made.
6. Stage of Use (System Maintenance) The usage phase is the stage where when the system has been finished designing and then successfully passes the stages of system testing and then it can be used [9].

3. Result And Discussion

Reasoning using the Sugeno fuzzy method is not much different from the Mamdani fuzzy reasoning technique, except that the output (consequent) of the system is not in the form of a fuzzy set but in the form of a constant or linear equation. MichioSugeno is a researcher proposing the use of singletons as a membership function of consequent [10] [4] [9].

Singleton is a fuzzy set that is equipped with a membership function which at a certain point must have a value and 0 outside that point. There are 2 Sugeno fuzzy models, as follows:

1. Fuzzy Sugeno Order-Zero Model. In general the form of the Zero Order fuzzy Sugeno model is:
   IF (x1 is A1) o (x2 is A2) o (x3 is A3) o ... o (xN is AN)
   THEN z = k
   with Ai is the first fuzzy set as antecedent, and k is a constant value consequent.
2. Sugeno Order-One Fuzzy Model. In general, the form of the Sugeno Order One fuzzy model is:
   IF (x1 is A1) o ... o (xN is AN)
   THEN $z = p_i * x1 + ... + pN * xN + q$

with A_i is the i-fuzzy set as antecedent, and pi is a value of the i and q constants which are consequent constants.

Since 1990, coffee quality standards in Indonesia have been implemented based on the defect value system that refers to SNI 01-2907-2008. Quality standards are very important to be used as guidance in quality control of coffee. Following is the specification table for coffee bean quality requirements:

Table 1. Specifications for quality requirements of coffee beans

No.	Test type	Unit	Requirements
1.	Water content (b / b)	%	Maksimum 12
2.	The amount of dirt	%	Maksimum 0.5
3.	The amount of dirt	-	Free
4.	Seeds smell bad and have mold	-	Free
5.	Large size seeds, do not pass round hole sieves measuring 7.5 mm in diameter (b / b)	%	Maximum escape 2.5
6.	Medium-sized seeds of hole size 6.5 mm (b / b)	%	Maximum escape 2.5
7.	Small size BIji passes round hole sieve size 6.5 m in diameter, does not pass round hole sieve size 5.5 mm in diameter (b / b)	%	Maximum escape 2.5

Source: Agricultural Research and Development Center, 2008

In identifying the quality of coffee beans it is divided into 3 parts of quality, namely;

1. The first quality includes, having yields ranging from 75% to 84.5%, the ash content contained between 1.2559% to 2.9870%, the caffeine content which is between 0.2353% to 0.4887% and total acid content ranges from 1.2372% to 2.2296%. The characteristics of this coffee bean are creamy, flavored coffee (fresh), large and oval seeds
2. The second quality includes, having yields ranging from 35% to 64.5%, ash content ranges from 1,000% to 2,000%, caffeine levels range from 0.2353% to 0.4887% and total acid levels range from 1.0050% up to 1.1153%. The characteristics of this coffee bean are bluish gray, flavored with a mixture of coffee and soil, medium and half oval
3. The third quality includes, has a yield ranging from 10% to 30.5%, ash content ranges from 0.1004% to 0.2009%, caffeine content ranges from 0.1991% to 0.1993% and levels total acid ranges from 0.3256% to 0.1934%. The characteristics of this coffee bean are dark brown, rotten flavor (not fresh anymore), defective seeds and irregular shape.

In the fuzzy logic method, the sugeno model criteria needed to identify the quality of coffee beans are as follows:

1. Color

Following is the set and value of the color classification to identify the quality of coffee beans:

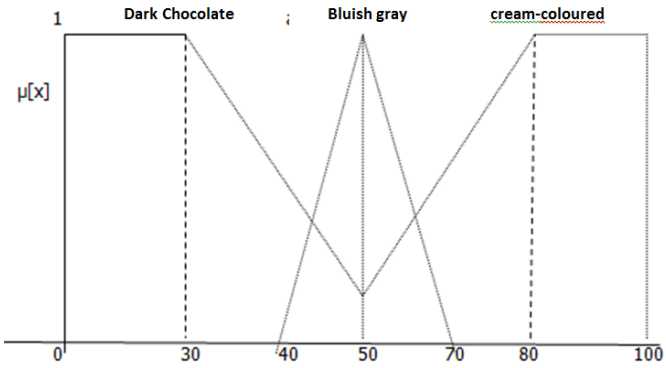

Figure 2. The Fuzzy Color Classification Set

Table 2. Color Classification

Set Clasification	Value
Cream-coloured	100-80
Bluish gray	70-40
Dark Chocolate	30-0

2. Aroma

Following is the set and value of the aroma classification to identify the quality of coffee beans:

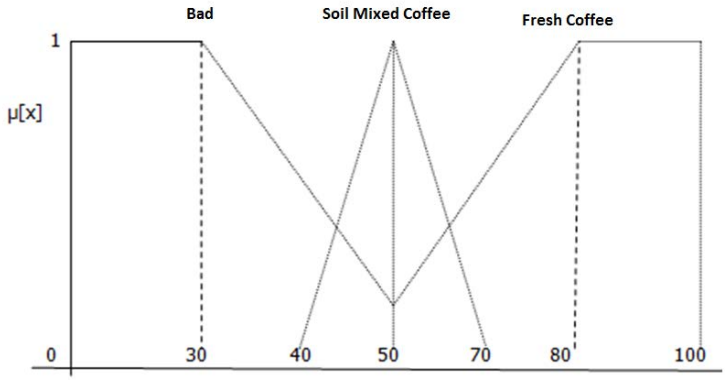

Figure 3. Fuzzy set of aroma classification

Table 3. Aroma Classification

Set Clasification	Value
Fresh Coffee	100-80
Soil Mixed Coffee	70-50
Bad	40-0

3. Texture

Next is the set and value of the texture classification to identify the quality of coffee beans:

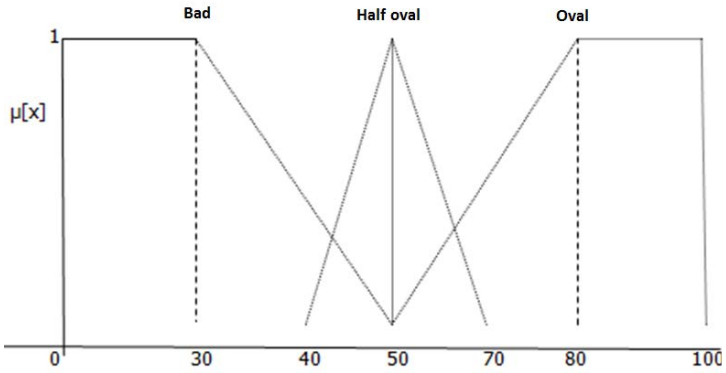

Figure 4. Fuzzy set of texture classifications

Table 4. Texture Classification

Set Clasification	Value
Oval	100-70
Half Oval	60-40
Bad	30-0

4. Quality Sets and Values

The following is the set and value of the quality classification for identifying coffee beans:

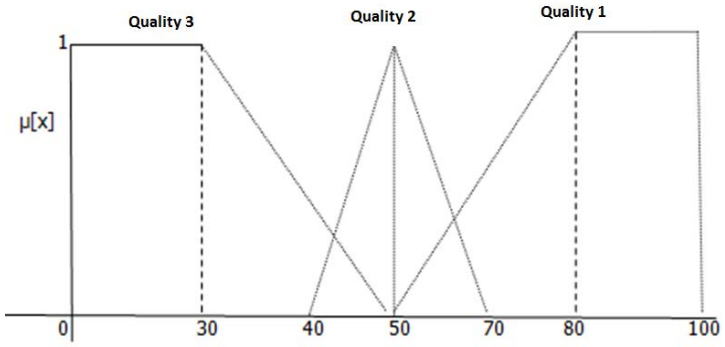

Figure 5. Fuzzy set of quality classification r

Table 5. Set of Quality of Coffee Beans

Set	Value	Information	Characteristic features
Quality 1	100-80	Good	Creamy Color, Coffee Scented and Oval Texture
Quality 2	70-50	Medium	Bluish Gray, Scented Coffee smells a little oval-shaped texture
Quality 3	40-0	Bad	Dark brown, rotten, damaged / deformed

In working with the zero-order sugeno method, first determine its fuzzyfication as follows:

1. First Quality [100-80] = coffee beans are creamy, flavored coffee (fresh), oval textured
2. Second Quality [70-40] = Coffee beans are bluish gray, have coffee flavor and are slightly earthy and half oval textured
3. Third Quality [30-0] = Coffee beans are dark brown, have a bad smell and are badly textured / physically disabled

The rule of fuzzyfication will be formed rule can be seen in the following table 3 bellow,

Table 6. Inference rule

Fuzzy	**Rule (IF)**	**Avarage (THEN)**	**Result**	
			Set	**Information**
[R1]	Creamy coffee beans (100) And Fresh aroma (100) And Oval texture(100)	(Z)= (100+100+100) / 3 (Z)= 100	Quality 1	Baik
[R2]	Creamy color (90) And the aroma mixed with a little soil (70) And Oval texture(80)	(Z)= (90+70+80) / 3 (Z)= 80	Quality 1	Baik
[R3]	Creamy color (80) And foul smell (40) And Oval texture(80	(Z)= (80+40+80) / 3 (Z)= 66,6	Quality 2	Medium
[R4]	Bluish gray (70) And Fresh Aroma(90) And Oval texture(80)	(Z)= (70+90+80) / 3 (Z)= 80	Quality 1	Baik
[R5]	Bluish gray (70) And the aroma mixed with a little soil (70) And Oval texture(80)	(Z)= (70+70+80) / 3 (Z)= 73,3	Quality 2	Medium
[R6]	Bluish gray (70) And foul smell (40) And Oval texture(80)	(Z)= (70+40+80) / 3 (Z)= 63,3	Quality 2	Medium
[R7]	Dark brown color (30) And Fresh aroma (90) And Oval texture(80)	(Z)= (30+90+80) / 3 (Z)= 63,3	Quality 2	Medium
[R8]	Dark brown color (30) And the aroma mixed with a little soil (60) And Oval texture(80)	(Z)= (30+60+80) / 3 (Z)= 56,6	Quality 2	Medium
[R9]	Dark brown color (30) And foul smell (40) And Oval texture(80)	(Z)= (30+40+80) / 3 (Z)= 50	Quality 2	Medium
[R10]	Creamy color (80) And Fresh aroma (90) And Half texture Oval (60)	(Z)= (80+90+60) / 3 (Z)= 76,6	Quality 2	Medium
[R11]	Creamy color (90) And the aroma mixed with a little soil (60) And Half texture Oval (50)	(Z)= (90+60+50) / 3 (Z)= 66.6	Quality 2	Medium
[R12]	Creamy color (90) And foul smell (10) And Half texture Oval (60)	(Z)= (90+10+60) / 3 (Z)= 53,3	Quality 2	Medium
[R13]	Bluish gray (70) And Fresh aroma (90) And Half texture Oval (60)	(Z)= (70+90+60) / 3 (Z)= 73.3	Quality 2	Medium
[R14]	Bluish gray (60) And the aroma mixed with a little soil (60) And Half texture Oval (60)	(Z)= (60+60+60) / 3 (Z)= 60	Quality 2	Medium
[R15]	Bluish gray (60) And foul smell (20) And Half texture Oval (60)	(Z)= (60+60+20) / 3 (Z)= 46,6	Quality 2	Medium
[R16]	Dark brown color (30) And Fresh aroma (80) And Half texture Oval (60)	(Z)= (30+80+60) / 3 (Z)= 50	Quality 2	Medium
[R17]	Dark brown color (30) And aroma mixed with a little soil (60) And Half texture Oval (60)	(Z)= (30+60+60) / 3 (Z)= 50	Quality 2	Medium
[R18]	Dark brown color (20) And foul smell (20) And Half texture Oval (50)	(Z)= (20+20+50) / 3 (Z)= 30	Quality 3	Bad
[R19]	Creamy color (80) And Fresh aroma (80) And Damaged texture (20)	(Z)= (80+80+20) / 3 (Z)= 60	Quality 2	Medium
[R20]	Creamy color (80) And the aroma mixed with a little soil (60) And Damaged texture (20)	(Z)= (80+60+20) / 3 (Z)= 56,6	Quality 2	Medium
[R21]	Creamy color (80) And foul smell (10)	(Z)= (80+10+10) / 3	Quality 3	Bad

Fuzzy	**Rule (IF)**	**Avarage (THEN)**	**Result**	
			Set	**Information**
	And Damaged texture (10)	(Z)= 33.3		
[R22]	Bluish gray (70) And Fresh aroma (90) And Damaged texture (20)	(Z)= (70+90+20) / 3 (Z)= 60	Quality 2	Medium
[R23]	Bluish gray (60) And the aroma mixed with a little soil (60) And Damaged texture (10)	(Z)= (60+60+10) / 3 (Z)= 43.3	Quality 2	Medium
[R24]	Bluish gray (60) And foul smell (20) And Damaged texture (10)	(Z)= (60+20+10) / 3 (Z)= 30	Quality 3	Bad
[R25]	Dark brown color (30) And Fresh aroma (80) And Damaged texture (20)	(Z)= (30+80+20) / 3 (Z)= 43.3	Quality 2	Medium
[R26]	Dark brown color (30) And the aroma mixed with a little soil (60)And Damaged texture (20)	(Z)= (30+60+20) / 3 (Z)= 36,6	Quality 3	Bad
[R27]	Dark brown color (20) And foul smell (30) And Damaged texture (20)	(Z)= (20+30+20) / 3 (Z)= 26,6	Quality 3	Bad
[R28]	Creamy color (90) And Fresh aroma (80) And Damaged texture (30)	(Z)= (90+80+30) / 3 (Z)= 66,6	Quality 2	Medium
[R29]	Creamy color (90)And the aroma mixed with a little soil (70) And Damaged texture (30)	(Z)= (90+70+30) / 3 (Z)= 63,3	Quality 2	Medium
[R30]	Creamy color (90) And foul smell (40) And Damaged texture (30)	(Z)= (90+40+30) / 3 (Z)= 53,3	Quality 2	Medium
[R31]	Bluish gray (60) And Fresh aroma (70) And Damaged texture (20)	Z)= (60+70+20) / 3 (Z)= 50	Quality 2	Medium
[R32]	Bluish gray (60) And the aroma mixed with a little soil (60) And Damaged texture (20)	(Z)= (60+60+20) / 3 (Z)= 46,6	Quality 3	Bad
[R33]	Bluish gray (70) And foul smell (30) And Damaged texture (20)	(Z)= (70+30+20) / 3 (Z)= 40	Quality 3	Bad
[R34]	Dark brown color (30) And Fresh aroma (80) And Damaged texture (20)	(Z)= (30+80+20) / 3 (Z)= 43,3	Quality 3	Bad
[R35]	Dark brown color (30) And the aroma mixed with a little soil (60) And Damaged texture (20)	(Z)= (30+60+20) / 3 (Z)= 36,6	Quality 3	Bad
[R36]	Dark brown color (20) And foul smell (20) And Damaged texture (20)	(Z)= (20+20+20) / 3 (Z)= 20	Quality 3	Bad

Next to get a conclusion from defuzzification, mean weighted average calculation is used. To get the results of identifying the quality of the first coffee beans needed is inputting the type of coffee, the second inputting the color of the coffee beans (after the coffee beans are ground), the third inputting the aroma of the coffee beans and the fourth inputing the texture of the coffee beans so that the results can be known.

4. Conclusion

As for the results of the discussion and the results of the research conducted, the researchers took several conclusions including:

1. The quality of coffee beans can be determined by the type of coffee, the second input color from the coffee beans (after the coffee beans are ground), the third input the aroma from the coffee beans and the fourth input the texture of the coffee beans.

2. Identification of the quality of coffee beans using Fuzzy Sugeno, which uses zero order Fuzzy Sugeno model by using as many as 36 rules according to the need to provide quality conclusions from the identification results.
3. To find out the characteristics of the quality of identification of coffee beans and this identification technique can also be developed with other methods such as Tsukamoto, Mamdani, and other methods.

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