Fuzzy Technology Designfor Early Detection of Diseases in Tobacco Plants

by Saiful Anwar

Article

Fuzzy Technology Design for Early Detection of Diseases in Tobacco Plants

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Abstract: Tobacco is an agricultural product that uses leaves to be processed into pesticides, medicines and cigarettes. Tobacco quality is determined by plant maintenance and reduced pest and disease attacks. To avoid these disturbances, control is needed quickly, precisely and accurately so that the tobacco plant disease cannot spread throughout agricultural land. In making fuzzy, diseases and symptoms in tobacco plants are used as a rule base in making a fuzzy expert system. The expert system created in this research is an expert system using the concept of fuzzy logic to diagnose tobacco plant diseases, using the Mamdani inference method and the defuzzification process using the centroid method (firmness value) to get the right conclusions in diagnosing tobacco plant diseases. From the results of Mamdani's design and manual fuzzy calculations, it can be concluded that the design is ready to be further implemented into the required programming language. From the sample calculation results, it was found that damping off disease has a moderate degree of risk with a value of 41.54. With the construction of this system, it will provide easy information for farmers to carry out and find out what symptoms are contracting diseases in tobacco plants.

Keywords: expert system, fuzzy expert system, mamdani, tobacco disease

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1. Introduction

Tobacco is a type of seasonal plant that belongs to plantation crops. This plant is spread throughout the archipelago and has many uses, especially as raw material for making cigarettes [1].

In Indonesia, good (commercial) tobacco is only produced in certain areas. Tambakau quality is determined by its location and processing. In the Lombok area, tobacco plants are generally grown in the East Lombok area, but the quality of the tobacco produced is still not good, this is due to the many biotic disturbances or OPT (Plant Pest Organisms). (disease). To avoid these disturbances, control is needed quickly, precisely and accurately so that the tobacco plant disease cannot spread throughout agricultural land. In this case, the role of an expert is needed to be relied on to know and determine the type of disease in order to carry out proper control, but in reality not all experts can provide their knowledge due to time constraints and others, so other alternatives are needed to solve the problem.

So the solution offered is the development of a fuzzy expert system for early detection of diseases in tobacco plants. Expert systems are considered as knowledge-based intuitive and declarative systems [2]. Then the fuzzy system can simultaneously process linguistic and numerical information [3], so that the fuzzy expert system is very suitable for use in the tobacco disease detection process.

The fuzzy inference system works in three stages, namely fuzzification, inference system and defuzzification [4]. The method of knowledge representation and fuzzy reasoning is used to transform uncertain system input into linguistic information (natural language/fuzzy) [5].

2. Materials and Methods

The stages in the process of designing this fuzzy expert system are as follows:

2.1. System Requirements Analysis

The requirements needed to create a fuzzy system. The fuzzy system created with the mamdani fuzzy method consists of 3 elements that must exist, namely: input data, process and output data, each of these elements will be explained below. :

a. Input

The input data here are the symptoms of tobacco plant diseases which are expressed in the form of variables, where each variable uses a fuzzy set, each of which has a numerical or crisp (firm) value in a particular domain [6], [7]. The crisp value of the fuzzy set indicates the value or weight of the frequency or severity of disease symptoms in the tobacco plant. The number of input variables used is 21 variables, where each variable contains 3 fuzzy sets so that the total fuzzy sets used are 63 sets.

The design of the fuzzy system uses shoulder curves for low and high sets, while triangular curves are used for medium sets. Where each domain has the same value, namely Mild [0 0 20 50], Moderate [20 50 80] and Heavy [50 80 100 100]. There are 21 fuzzy input variables used as shown in the following table:

Table 1. Fuzzy Input Variables

Nama Variabel		
1. Shrinking root neck (srn)	7. Black Roots (blr)	13. Root speckled with white spots (rss)
2. Stems dry out (sdo)	8. Leaves with holes (lwh)	14. Young leaves are yellow and wrinkled (ylw)
3. Blackened Stems (bst)	9. Leaves are damaged and easily torn (lde)	15. Stunted growth (stg)
4. Stem crimped (scr)	10. Irregular and repeated leaf spots (irs)	16. Bone leaves bent (blb)
5. Leaves with brownish white spots (lbw)	11. The petioles turn yellow (pty)	17. Leaves wrinkled and rough (lwr)
6. Leaves limp and die (lld)	12. Leaves rot	

Meanwhile, there were 8 fuzzy output variables used, namely scorched stems (sst), dead weeds (dew), brown spot leaves (bsl), leaf rot (ler), cucumber mosaic (ccm), tobacco mosaic (tom) and tobacco cracker virus (tcv).

b. Process

According to research [8], the maximum number of fuzzy rules that are formed using the formula:

Maximum number of rules = number of membership input 1 x number of memberships 2 x number of memberships n.

The example of damping off disease consists of 4 variables and 3 fuzzy sets, so the number of rules formed is 3x3x3x3 = 34 = 81 rules. So that the results of the formation of fuzzy fuzzy are as follows:

Table 2. Formation of Fuzzy Rules

R1	IF root neck shrinks is LIGHT And Stem dries up is LIGHT And Stem in soil rots is LIGHT And Stem wrinkled is LIGHT Then Scorched Stem is LIGHT
R2	IF root neck shrinks is LIGHT And Stem dries up is LIGHT And Stem in soil rots is LIGHT And Stem wrinkled is MODERATE Then Scorched Stem is MILD
R3	IF root neck shrinks is LIGHT And Stem dries up is LIGHT And Stem in soil rots is LIGHT And Stem wrinkled is SEVERE Then Scorched Stem is LIGHT

R4	IF root neck shrinks is LIGHT And Stem dries up is LIGHT And Stem in soil rots is MODERATE And Stem wrinkled is LIGHT Then Scorched Stem is LIGHT
R5	IF root neck shrinks is MILD And stem dries up is MILD And Stem in soil rots is MODERATE And Stem wrinkled is MODERATE Then scorched stem is MILD
R6	IF root neck shrinks is LIGHT And Stem dries up is LIGHT And Stem rotting in soil is MODERATE And Stem wrinkled is SEVERE Then Scorched Stem is LIGHT
R7	IF root neck shrinks is LIGHT The stem dries up is LIGHT And The stem in the soil rots is HEAVY And The stem wrinkled is LIGHT Then Scorched Stem is LIGHT
R8	IF root neck shrinks is LIGHT And Stem dries up is LIGHT And Stem rotting in soil is SEVERE And Stem wrinkled is MODERATE Then Scorched Stem is LIGHT
R9	IF root neck shrinks is LIGHT And root neck is LIGHT And Stem dries up is LIGHT And Stem rotting in soil is SEVERE And Stem wrinkled is HEAVY Then Scorched Stem is HEAVY
R10	IF root neck shrinks is mild And stem dries up is MODERATE And Stem in soil rots is mild And Stem wrinkled is mild Then charred stem is MILD
….	……………………………..………………………………………………………..
R81	IF root neck shrinks is WEIGHT And stem dries up is WEIGHT And Stem rotting in soil is WEIGHT And wrinkled stem is WEIGHT Then Scorched Stem is WEIGHT

c. Output

Output that displays the results in the form of message stating a conclusion about the most potential disease in tobacco plant diseases based on the results of an analysis of the disease and the resulting value when processed. The percentage of match rates starts from 0% -100%.

2.2. System Design

The following is the design of the developed fuzzy expert system model:

a. Usecase diagram

The relationship between actors and the system is shown in the following use case diagram:

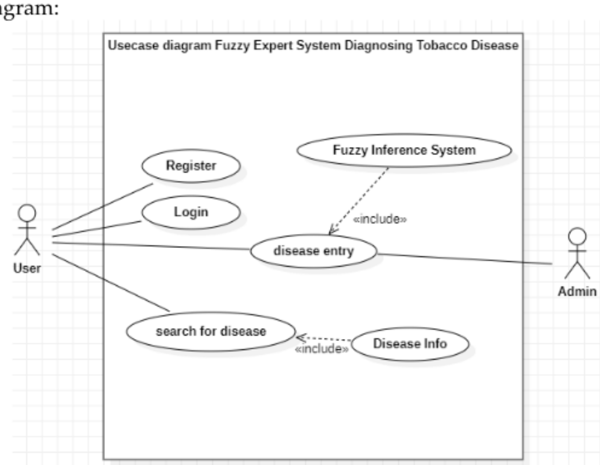

Figure 1. Usecase Diagram

In Figure 1, there are 2 actors, namely users and admins. The user actor must first register before logging into the system to get a user account. Meanwhile, the admin actor logs into the system to enter data in the form of disease data, user symptoms and users. In addition, the admin can also search for the symptoms or diseases that you want to update.

b. Class Diagram

Figure 2 below explains the class diagram which shows the relationship between classes/tables in the system being developed along with the degree of the relationship.

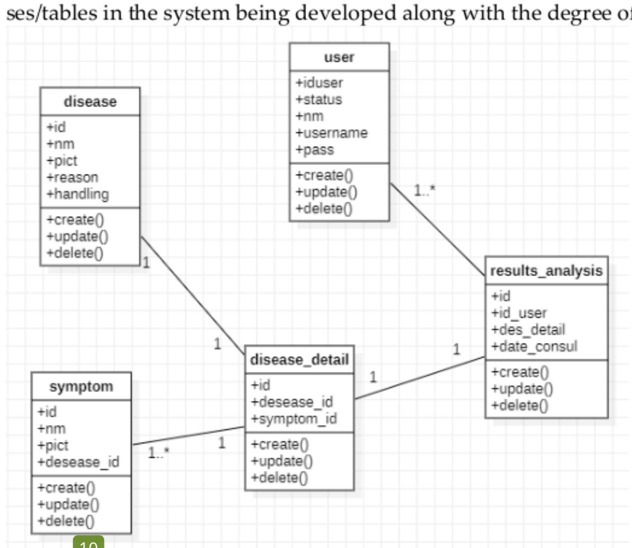

Figure 2. Class Diagram

c. Activity Diagram

Furthermore, the activity diagram developed as shown in Figure 3 below:

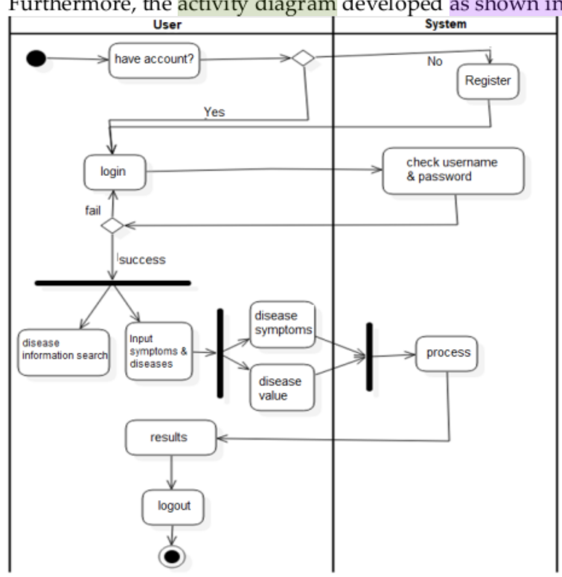

Figure 3. Activity Diagram

d. Sequence Diagram

While the sequence diagram as shown in Figure 4 below::

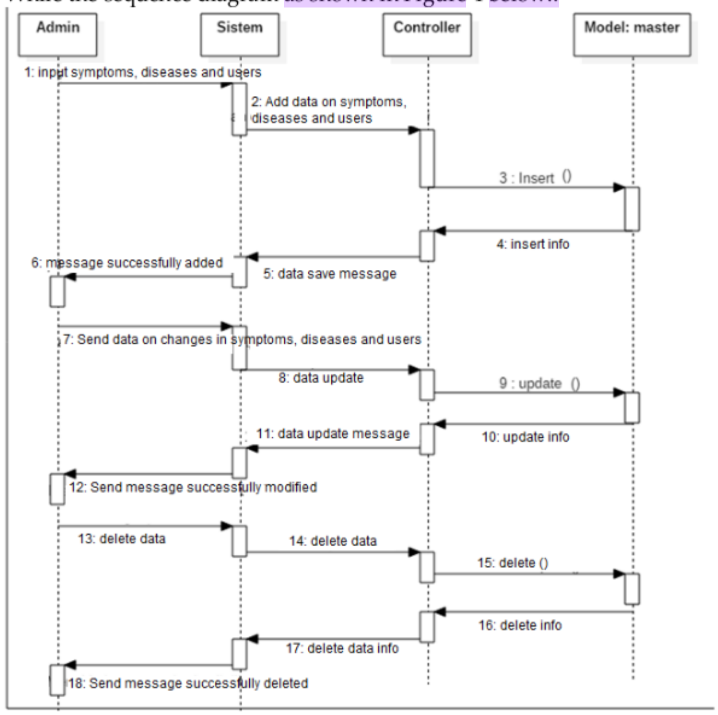

Figure 4. Sequence Diagram

2.3. Mamdani Fuzzy Calculations

In this theoretical trial, manual calculations will be carried out for the mamdani inference system to prove the similarity of the results of the system that has been built. The following are the stages for producing output in the system using the mamdani fuzzy inference system, namely fuzzification, fuzzy logic operations, implications, aggregation and defuzzification [9].

For this calculation, take the example of tobacco disease plants with stem scorch disease. The following are the symptoms that occur, namely the root neck shrinks (25), the stem dries up (35), the stem rots in the soil (60), the stem is wrinkled (80). The following is a calculation using a fuzzy inference system:

a. Fuzzification

Fuzzification function is to determine the degree of membership of a number of inputs in the fuzzy set [10], [7]. Here are the membership functions for all variables:

$$\mu_{Ringan}[a] = \begin{cases} 1; a \leq 20 \\ \frac{50-a}{30}; 20 \leq a \leq 50 \\ 0; a \leq 50 \end{cases}$$

$$\mu_{Sedang}[a] = \begin{cases} 0; a \leq 20 \; or \; a \geq 80 \\ \frac{a-20}{30}; 20 \leq a \leq 50 \\ \frac{80-a}{30}; 50 \leq a \leq 80 \end{cases}$$

$$\mu_{Berat}[a] = \begin{cases} 0; a \leq 50 \\ \frac{a-50}{30}; 50 \leq a \leq 80 \\ 1; a \leq 80 \end{cases}$$

The following is the fuzzification process on the root neck variable shrinking with input (a) = 25

$\mu_{\text{LeherakamengecilRingan}}[25] = \frac{50-25}{30} = \frac{25}{30} = 0.83$

$\mu_{\text{LeherakamengecilSedang}}[25] = \frac{25-20}{30} = \frac{5}{30} = 0.17$

$\mu_{\text{LeherakamengecilBerat}}[25] = 0$

The following is the fuzzification process on the dry stem neck variable with input (a) = 35

$\mu_{\text{BatangmengeringRingan}}[35] = \frac{50-35}{30} = \frac{15}{30} = 0.5$

$\mu_{\text{BatangmengeringSedang}}[35] = \frac{35-20}{30} = \frac{15}{30} = 0.5$

$\mu_{\text{BatangmengeringBerat}}[35] = 0$

Here is the process of fuzzification on variable stems in decomposing soil (a) = 60

$\mu_{\text{batangmembusukRingan}}[60] = 0$

$\mu_{\text{BatangmembusukSedang}}[60] = \frac{80-60}{30} = \frac{20}{30} = 0.67$

$\mu_{\text{BatangmengeringBerat}}[60] = \frac{60-50}{30} = \frac{10}{30} = 0.33$

The following is the fuzzification process on the wrinkled stem variable (a) = 80

$\mu_{\text{BatangberkerutRingan}}[80] = 0$

$\mu_{\text{BatangberkerutSedang}}[80] = \frac{80-80}{30} = \frac{0}{30} = 0$

$\mu_{\text{BatangberkerutBerat}}[80] = 1$

b. Implications

Rule 6

[R6] IF root neck shrinks is LIGHT And Stem dries up is LIGHT And Stem naturally rots soil is MODERATE And Stem wrinkled is SEVERE Then Scorched Stem is LIGHT

$\alpha_6 = \mu_{\text{PredikatR6}} = \min(\mu_{\text{LeherakarmengecilRingan}}[25] \cap \mu_{\text{BatangmngringRingan}}[35] \cap \mu_{\text{BatangdlmtnhMembusukSedang}}[60] \cap \mu_{\text{BatangberkerutSedang}}[80])$

$= \min(0.83;0.5;0.67;1) = 0.5$

Rule 9

[R9] IF root neck shrinks is LIGHT And Stem dries up is LIGHT And Stem in soil rots is SEVERE And Stem wrinkled is SEVERE Then Scorched Stem is SEVERE

$\alpha_9 = \mu_{\text{PredikatR9}} = \min(\mu_{\text{LeherakarmengecilRingan}}[25] \cap \mu_{\text{BatangmngringRingan}}[35] \cap \mu_{\text{BatangdlmtnhMembusukBerat}}[60] \cap \mu_{\text{BatangberkerutBerat}}[80])$

$= \min(0.83;0.5;0.33;1) = 0.33$

Rule 15

[R15] IF root neck shrinks is LIGHT And Stem dries up is MODERATE And Stem in soil rots is MODERATE And Stem wrinkled is SEVERE Then Scorched Stem is MODERATE

$$\alpha_{15} = \mu_{PredikatR15} = \min(\mu_{LeherakarmengecilRingan}[25] \cap \mu_{BatangmngringSedang}[35] \cap \mu_{BatangdlmtnhMembusukSedang}[60] \cap \mu_{BatangberkerutBerat}[80])$$

= min a(0.83;0.5;0.67;1) = 0.5

Rule 18

[R18] IF root neck shrinks is LIGHT And Stem dries up is MODERATE And Stem rotting in soil is SEVERE And Stem wrinkled is SEVERE Then Scorched Stem is MODERATE

$$\alpha_{18} = \mu_{PredikatR18} = \min(\mu_{LeherakarmengecilRingan}[25] \cap \mu_{BatangmngringSedang}[35] \cap \mu_{BatangdlmtnhMembusukBerat}[60] \cap \mu_{BatangberkerutBerat}[80])$$

= min a(0.83;0.5;0.33;1) = 0..33

Rule 33

[R33] IF root neck shrinks is MODERATE And Stems dry up is LIGHT And Stems rot in soil is MODERATE And Stems wrinkled is SEVERE Then Scorched Stems is MODERATE

$$\alpha_{33} = \mu_{PredikatR33} = \min(\mu_{LeherakarmengecilSedang}[25] \cap \mu_{BatangmngringRingan}[35] \cap \mu_{BatangdlmtnhMembusukSedang}[60] \cap \mu_{BatangberkerutBerat}[80])$$

= min a(0.17;0.5;0.67;1) = 0.17

Rule 36

[R36] IF root neck shrinks is MODERATE And the stem dries up is LIGHT And The stem in the soil rots is SEVERE And The stem wrinkled is SEVERE Then Scorched Stem is SEVERE

$$\alpha_{36} = \mu_{PredikatR36} = \min(\mu_{LeherakarmengecilSedang}[25] \cap \mu_{BatangmngringRingan}[35] \cap \mu_{BatangdlmtnhMembusukBerat}[60] \cap \mu_{BatangberkerutBerat}[80])$$

= min a(0.17;0.5;0.33;1) = 0.17

Rule 42

[R42] IF root neck shrinks is MODERATE And the stem dries up is MODERATE And The stem rots in the soil is MODERATE And The stem is wrinkled is SEVERE Then Scorched Stem is MODERATE

$$\alpha_{42} = \mu_{PredikatR42} = \min(\mu_{LeherakarmengecilSedang}[25] \cap \mu_{BatangmngringSedang}[35] \cap \mu_{BatangdlmtnhMembusukSedang}[60] \cap \mu_{BatangberkerutBerat}[80])$$

= min a(0.17;0.5;0.67;1) = 0.17

Rule 44

[R44] IF *root neck shrinks* is MODERATE And the *stem dries up* is MODERATE And *stem rotting in soil* is SEVERE And stem wrinkled is MODERATE Then Scorched Stem is MODERATE

$$\alpha_{44} = \mu_{PredikatR44} = \min(\mu_{LeherakarmengecilSedang}[25] \cap \mu_{BatangmngringSedang}[35] \cap \mu_{BatangdlmtnhMembusukBerat}[60] \cap \mu_{BatangberkerutSedang}[80])$$

$$= \min a(0.17;0.5;0.33;0)$$

$$= 0$$

c. Agregations

The function of aggregation or composition of all rules is to obtain a single set of output from a set of rules resulting from implication processing with the MIN function [11], [12]. The results of this aggregation process will then be used to find the area or fuzzy area solutions using the defuzzification process with the centroid method [6], [13].

The following is an image showing the implications for a set of rules which will then be used for the aggregation process:

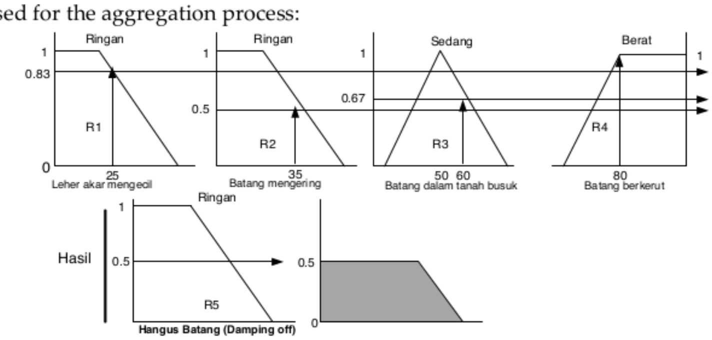

Figure 5. The result of the implication function for rule 6

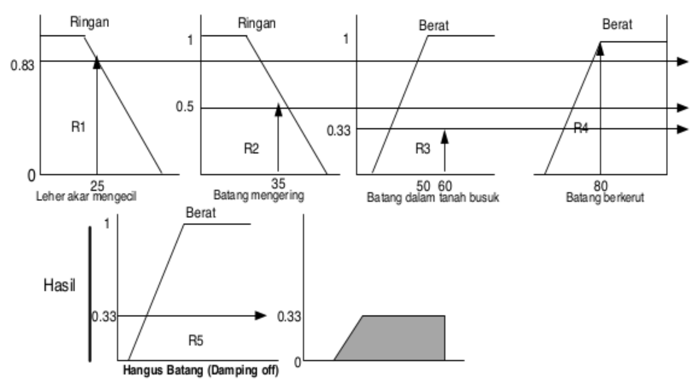

Figure 6. The result of the implication function for rule 9

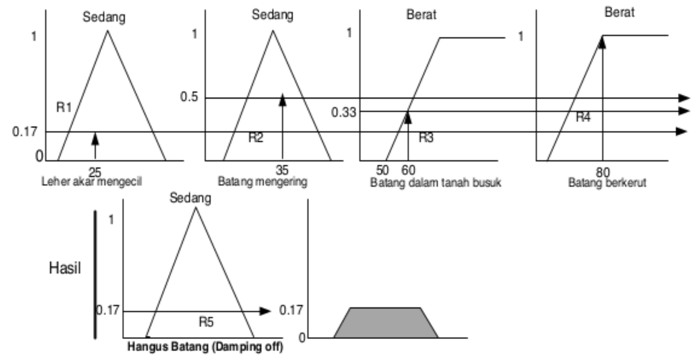

Figure 7. The result of the implication function for rule 15

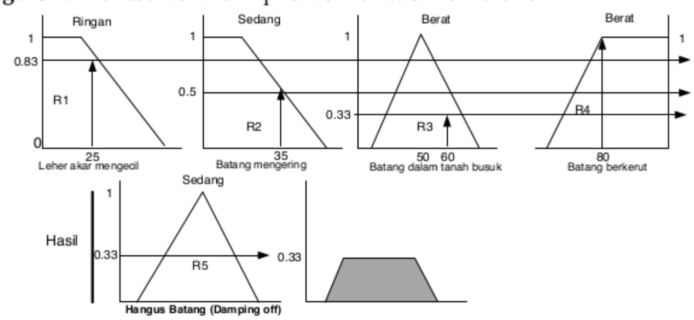

Figure 8. The result of the implication function for rule 18

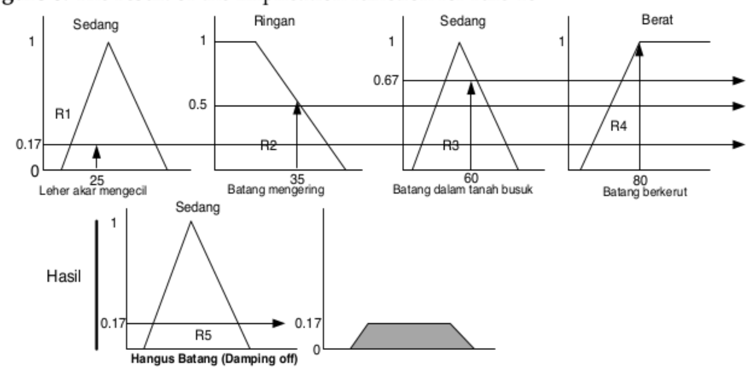

Figure 9. The result of the implication function for rule 33

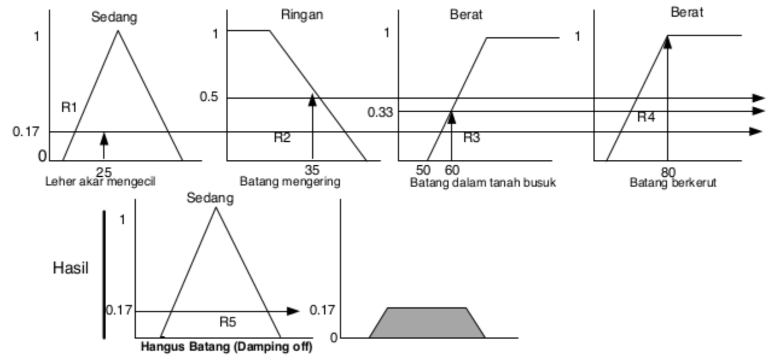

Figure 10. The result of the implication function for rule 36

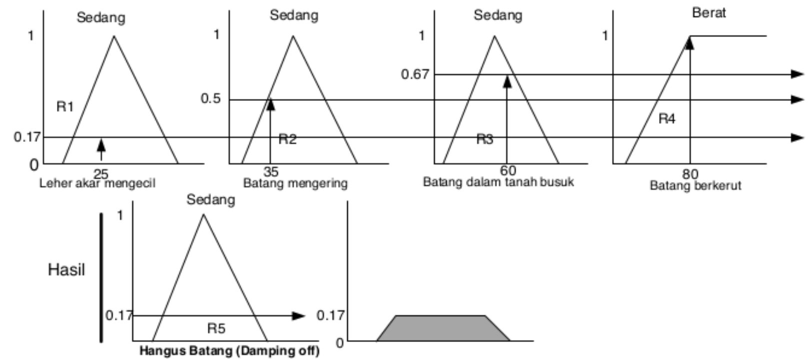

Figure 11. The result of the implication function for rule 42

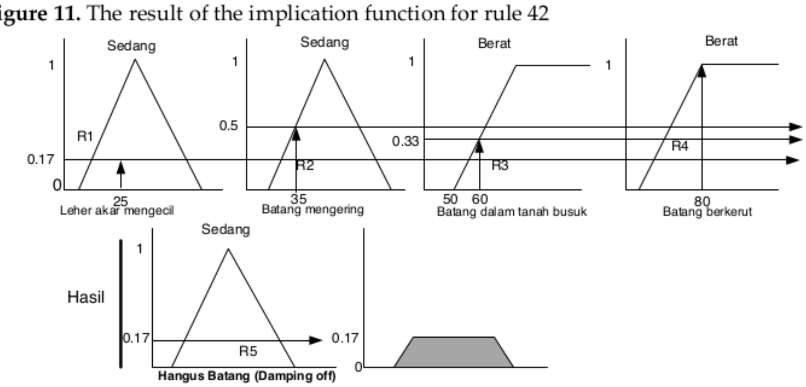

Figure 12. The result of the implication function for rule 44

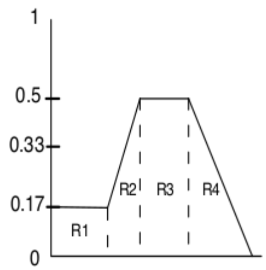

Figure 13. Result Area of Aggression (Solution Fuzzy Area)

So the new membership function for the composition of all outputs (fuzzy/sf solution) is as follows:

$$\mu_{SF}[a] = \begin{cases} 0.17; a \leq 25.10 \\ \frac{a-20}{30}; 25.10 \leq a \leq 35.00 \\ 0.17; 25.1 \leq a \leq 74.9 \\ \frac{80-a}{30}; 74.9 \leq a \leq 80 \\ 0; a \geq 80 \end{cases}$$

d. Defuzzification

Next is the defuzzification process using the Centroid method [14], [15]. Previously in Figure 15, the result area was divided into 4 areas with their respective areas, namely A1, A2, A3, and A4. Where the moments to the value of each membership are M1, M2, M3, and M4

$$\mathrm{M1} = \int_0^{25.10} (0.17)\mathrm{z}\,\mathrm{dz}$$

$$= 0.17 \int_0^{25.10} z\,dz$$

$$= 0.17 \left[\frac{1}{2} z^2\right]_{0}^{25.10}$$

$$= 0.17 \left[\frac{1}{2}(25.10)^2 - \frac{1}{2}\,0^2\right] = 0.17 \times 315.005 = 53.55$$

$$\mathrm{M2} = \int_{25.10}^{35} (0.03\mathrm{z} - 0.67)\mathrm{z}\,\mathrm{dz}$$

$$= \int_{25.10}^{35} (0.03\mathrm{z}^2 - 0.67\mathrm{z})\,\mathrm{dz}$$

$$= \left[\frac{0.03}{3}\mathrm{z}^3 - \frac{0.67}{2}\mathrm{z}^2\right]_{25.10}^{35}$$

$$= [0.01\,(35)^3 - 0.335(35)^2] - [0.01\,(25.10)^3 - 0.335(25.10)^2]$$

$$= [428.75 - 410.375] - [158.13 - 211.05]$$

$$= 18.375 + 52.92 = 71.30$$

$$\mathrm{M3} = \int_{25.10}^{74.9} 0.17\mathrm{z}\,\mathrm{dz}$$

$$= 0.17 \int_{25.10}^{74.9} a \, da$$

$$= 0.17 \left[\frac{1}{2} a^2\right]_{25.10}^{74.90}$$

$$= 0.17 \left[\frac{1}{2}(74.90)^2 - \frac{1}{2}(25.10)^2\right]$$

$$= 0.17 \times (2805.005 - 315.005)$$

$$= 0.17 \times 2490$$

$$= 423.3$$

$$M4 = \int_{74.9}^{80} (-0.03a + 2.67)ada$$

$$= \int_{74.9}^{80} (-0.03a^2 + 2.67a) \, da$$

$$= \left[-\frac{0.03}{3} z^3 + \frac{2.67}{2} z^2\right]_{74.9}^{80}$$

$$= [-0.01 (80)^3 + 1.335(80)^2] - [-0.01 (74.9)^3 + 1.335(74.9)^2]$$

$$= [-5120 + 8544] - [-4201.89749 + 7489.36335]$$

$$= 3424 - 3287.46586$$

$$= 136.53414$$

Calculating Area:

$$A1 = 25.10 \times 0.17 = 4.27$$

$$A2 = (0.17 + 0.5) \times \left[\frac{35 - 25.10}{2}\right] = (0.67 \times 4.95) = 3.32$$

$$A3 = (74.9 - 25.10) \times 0.17 = 8.46$$

$$A4 = (80 - 74.9) \times \left(\frac{0.17}{2}\right) = 0.43$$

Calculating Center Point (with respect to z):

$$z = \frac{53.55 + 71.30 + 423.3 + 136.5}{4.27 + 3.32 + 8.46 + 0.43} = \frac{684.65}{16.48} = 41.54$$

From the results of the calculation above, it was found that damping off had a moderate degree of risk with a value of 41.54.

4. Conclusions

From the results of Mamdani's design and manual fuzzy calculations, it can be concluded that the design is ready to be further implemented into the required programming language. From the sample calculation results, it was found that damping off disease has a moderate degree of risk with a value of 41.54. So that suggestions for further research can develop this research in terms of application development based on the results of the design that has been done.

References

[1] F. K. Neighbor, P. Tembakau, and F. K. Neighbor, "Jurnal Smart Teknologi Diagnosa Penyakit Pada Tanaman Tembakau Di Kabupaten Jember Menggunakan Metode Fuzzy K-Nearst Neighbor Diagnosis Of Disease In Tobacco Plant In Jember Regency Using Fuzzy K-Nearst Neighbor Method Jurnal Smart Teknologi," vol. 3, no. 6, pp. 646–651, 2022.

[2] A. Pakniyat, R. Hosseini, and M. Mazinai, "A Fuzzy Expert System for Star Classification Based on Photometry," *Int. J. Fuzzy Syst. Appl.*, vol. 5, no. 3, pp. 109–119, 2016, doi: 10.4018/ijfsa.2016070106.

[3] P. Liu, "Mamdani fuzzy system: universal approximator to a class of random processes," *IEEE Trans. Fuzzy Syst.*, vol. 10, no. 6, pp. 756–766, 2002, doi: 10.1109/tfuzz.2002.805890.

[4] W. Ben Tagherouit, S. Bennis, and J. Bengassem, "A Fuzzy Expert System for Prioritizing Rehabilitation of Sewer Networks," *Comput. Civ. Infrastruct. Eng.*, vol. 26, no. 2, pp. 146–152, Feb. 2011, doi: 10.1111/j.1467-8667.2010.00673.x.

[5] Z. Hu, "A fuzzy expert system for site characterization," *Expert Syst. Appl.*, vol. 24, no. 1, pp. 123–131, 2003, doi: 10.1016/s0957-4174(02)00090-8.

[6] Mamdani, "Application of Fuzzy Logic to Approximate Reasoning Using Linguistic Synthesis," *IEEE Trans. Comput.*, no. 12, pp. 1182–1191, 1977, doi: 10.1109/tc.1977.1674779.

[7] M. Abdulgader and D. Kaur, "Evolving Mamdani Fuzzy Rules Using Swarm Algorithms for Accurate Data Classification," *IEEE Access*, vol. 7, pp. 175907–175916, 2019, doi: 10.1109/access.2019.2957735.

[8] M. Yunus and M. R. T. Akbar, "Penerapan Algoritma Fuzzy Tahani Untuk Rekomendasi Penerima Beasiswa Peningkatan Prestasi Akademik," *JTIM J. Teknol. Inf. dan Multimed.*, vol. 3, no. 2 SE-Articles, Aug. 2021, doi: 10.35746/jtim.v3i2.161.

[9] Q. A. Nezhad, J. P. Zand, and S. S. Hoseini, "An Investigation on Fuzzy Logic Controllers (Takagi-Sugeno & Mamdani) in Inverse Pendulum System," *Int. J. Fuzzy Log. Syst.*, vol. 3, no. 3, pp. 1–14, 2013, doi: 10.5121/ijfls.2013.3301.

[10] H. Zhou and H. Ying, "A Method for Deriving the Analytical Structure of a Broad Class of Typical Interval Type-2 Mamdani Fuzzy Controllers," *IEEE Trans. Fuzzy Syst.*, vol. 21, no. 3, pp. 447–458, 2013, doi: 10.1109/tfuzz.2012.2226891.

[11] A. Nowé, "Sugeno, Mamdani, and fuzzy Mamdani controllers put in a uniform interpolation framework," *Int. J. Intell. Syst.*, vol. 13, no. 23, pp. 243–256, 1998, doi: 10.1002/(sici)1098-111x(199802/03)13:2/3<243::aid-int8>3.3.co;2-n.

[12] H. Wu and J. M. Mendel, "On Choosing Models for Linguistic Connector Words for Mamdani Fuzzy Logic Systems," *IEEE Trans. Fuzzy Syst.*, vol. 12, no. 1, pp. 29–44, 2004, doi: 10.1109/tfuzz.2003.822675.

[13] Y. Chen, F. Long, W. Kuang, and T. Zhang, "A method for predicting blast-induced ground vibration based on Mamdani Fuzzy Inference System," *J. Intell. & Fuzzy Syst.*, vol. 44, no. 5, pp. 7513–7522, 2023, doi: 10.3233/jifs-223195.

[14] A. Gegov, D. Sanders, and B. Vatchova, "Mamdani fuzzy networks with feedforward rule bases for complex systems modelling," *J. Intell. & Fuzzy Syst.*, vol. 30, no. 5, pp. 2623–2637, 2016, doi: 10.3233/ifs-151911.

[15] L. Magdalena and E. Trillas, "Abe Mamdani, in Memoriam," *Fuzzy Sets Syst.*, vol. 161, no. 23, pp. 2975–2977, 2010, doi: 10.1016/j.fss.2010.08.001.

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