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Fiber Optic Attenuation Analysis Based on Mamdani Fuzzy Logic in Gambir Area, Central Jakarta

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ABSTRACT

In this study, the authors conducted an analysis of the quality of fiber optic network maintenance based on attenuation value and maintenance time using fuzzy Mamdani logic and simulated using Matlab software, to improve accuracy in drawing conclusions on maintaining quality. This study uses a quantitative method, in which the author obtains a summary of customer data from PT. Telkom Indonesia in a period of 4 months of observation from August to November 2021. In August there were 776 customers, in September there were 362 customers, in October there were 359 customers, and in November 445 customers who underwent Indihome fiber optic cable maintenance. The test results with the centroid method with an input Handling Time of 1.5 hours and an Attenuation of 15 dB, then the output Repair Quality is 5.5 or categorized as Good. The greater the attenuation value generated, the more time it takes to maintain the IndiHome internet network disturbance. This is due to the many technical maintenance of fiber optic cables carried out by technicians to adjust for damage/trouble in the field. It is expected that maintenance can be carried out routinely in order to avoid fatal internet disturbances on the customer's side, and maximize maintenance time according to the dosage determined by the company, which is less than 3 hours, taking into account the work performance of technicians and also the quality of maintenance.

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1. INTRODUCTION

The need for reliable communication channels from all sides makes fiber optic networks increasingly demanded by the public, housing, offices, education, health, and others [1], [2]. With the fiber optic transmission line technology, internet service providers continue to develop services using fiber optic networks, one of which is the internet service provider IndiHome under the auspices of PT. Telkom Indonesia (Persero) [3], [4]. Based on customer data recap from PT. Telkom Indonesia (Persero) in the Gambir Area, Central Jakarta, within a period of 4 months of observation, it has been recorded that in August there were 776 subscribers, in September there were 362 subscribers, in October there were 359 subscribers, and in November 445 subscribers experienced IndiHome internet problems. The sensitivity of the fiber optic drop core cable causes attenuation or a decrease in signal power emitted by the optical source, Light Emitting Diode (LED) or Laser Diode (LD) caused by various factors [5], one of which is light scattering due to uneven connections or bending of the fiber optical so that the emitted power becomes weak. PT. Telkom Indonesia (Persero) has set the standard attenuation value for IndiHome internet services on customer devices in the range of -10 dBm to -25 dBm to maintain service quality and the standard sensitivity of customer device modems at -25 dBm [6], with repair time less than or equal to 3 (three) hours. If the measured results are outside the range of values that have been determined by PT. Telkom Indonesia (Persero), it can be concluded that indications of internet

disturbances must be followed up immediately so that the quality of IndiHome service improvements can be maximized.

Previously, many researchers have conducted data classification analysis, including in 2022 [7]–[9], according to the Exponential Loss Minimization for Learning Weighted Naive Bayes Classifiers study, this approach assumes that all characteristics are equally important. One way to get around this assumption and make the naive Bayes classification perform better is through attribute weighting. Then, in 2020 [9]–[12], similar to this study, a regularization method for increasing the generalizability of Class-Specific Attribute Weighted Naive Bayes (CAWNB) was proposed. This method could effectively strike a balance between discrimination power and generalizability. More specifically, by introducing the term "regularization," the proposed method, which is called "Regularized Naive Bayes" (RNB), could effectively capture the characteristics of the data when the dataset is large and exhibit strong generalization performance when the dataset is small. A similar study proposed a regularization technique to enhance the generalization capability of "Class-Specific Attribute Weighted Naive Bayes" (CAWNB), which could effectively strike a balance between. More specifically, the proposed method, known as Regularized Naive Bayes (RNB), can effectively capture data characteristics when the dataset is large and exhibit good generalization performance when the dataset is small by introducing the regularization term. Then, in 2019 [13], [14], to develop Mamdani fuzzy rules that provide a knowledge base for the precise classification of datasets, this paper proposes a fuzzy evolutionary system based on the Gray Wolf Optimizer (GWO) algorithm. After creating a grammar template in the form of fuzzy rules, the GWO algorithm is used to develop the fuzzy rules that are used to classify the datasets. Furthermore, in 2021 [15], the effectiveness of data-sentiment classification can be enhanced by using a brand-new Fuzzy Deep Learning Classifier (FDLC). Convolutional Neural Network (CNN) and Feedforward Neural Network (FFNN) are incorporated into the proposed FDLC to create an efficient automatic process for extracting features from collected unstructured data.

In 2019, attenuation analysis was carried out on the Fiber to The Home (FTTH) network, but it was only limited to experiments in the field with the help of an Optical Power Meter (OPM). On the basis of these problems, in this study the authors conducted an analysis of the quality of fiber optic network maintenance based on attenuation value and maintenance time using fuzzy mamdani logic and simulated using Matlab software, to improve accuracy in drawing conclusions on maintenance quality. The reason the author uses Mamdani fuzzy logic is because of its simple structure [16], [17]. Mamdani fuzzy logic uses min-max or max-product operations with a predetermined set of rules, namely the previous IF...AND...THEN. To get the output of this fuzzy logic, it takes 4 stages, namely the formation of fuzzy sets, the application of implication functions,the composition of rules, and defuzzification [18], [19]. From the results of this defuzzification, the authors can determine the decisions to be taken. In the formation of fuzzy sets, input is needed in the form of attenuation values in the High category (range 20-30 dB), Normal category (range 15-25 dB), Low category (range 10-20 dB). And also input in the form of repair time in the Fast category (range 0-1 hours), the Normal category (range 1-2 hours), and the Slow category (range 2-3 hours). So that a decision can be made based on the quality category of interruptions, namely the Very Good category (range 7-10), Good category (range 4-7), and Bad category (range (1-3). The occurrence of fatal internet disturbances on the customer's side, and maximizing repair time according to the dose determined by the company by paying attention to the work performance of technicians and also the quality of repairs.

2. METHODS

2.1. Research Stages

At this stage of the research process to collect data, the research stage method was carried out as follows: a) Formulation of the research problem, starting with analyzing the problems encountered in the field related to the fiber optic attenuation value and repair time related to Indihome internet service interruptions in the Gambir area, West Jakarta. ; b) Literature review, this is needed to get references related to the formulation of relevant problems. Literature sources are taken from books, journals, and other supporting scientific works; c) Data collection, the authors take the data to PT. Telkom Indonesia (Persero) Gambir Area Assurance Unit, Central Jakarta, Regional II; d) Interviews, the authors seek information from parties related to the handling of Indihome internet disturbances in order to support the smooth running of research, such as the use of Optical Power Meter (OPM) measuring instruments; e) Design of quality classification system for fiber optic cable repair using Mamdani fuzzy logic based on Matlab simulator; f) Testing and analyzing data on the quality classification of fiber optic cable repairs to determine if Indihome's internet service performance is in accordance with the company's Technical SLA (Assurance). To more easily understand the stages of this research, it can be seen in Fig. 1.

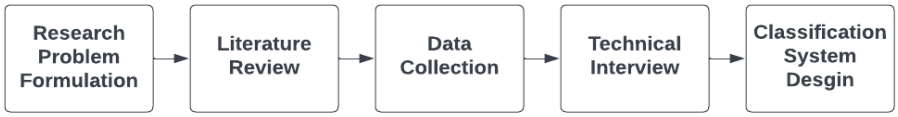

Fig. 1. Research Stages

2.2. Technical SLA (Assurance) 2022 PT. Telkom Indonesia (Persero)

Disruptions to the Indihome internet service are classified into 2 (two) parts, namely "services are not optimal", and "services cannot be used". The service cannot be used, it means the device is turned off, so PT. Telkom Indonesia (Persero) failed to monitor the network. In this case, it must be checked at the customer's site and resolved as soon as possible by the troubleshooting officer. The service is less than optimal, meaning that attenuation occurs in the range of -25 to -10 dBm so that the network from that service is called underspect [6]. Based on the results of interviews with Indihome's internet interference handling officers, there are points that cause internet disturbances that often occur, namely as follows [20]–[22]: 1) Drop core cable was broken by a rat; 2) High damping; 3) Fiber Core in ODP is broken/bent; 4) Fiber Core in ODC is broken/cracked; 5) Human error when accessing ODP and ODC. Table 1 shows the attenuation standards for the disturbance ticket processing from PT. Telkom Indonesia (Persero).

Timing of interruptions for Indihome internet service interruptions has been arranged by PT. Telkom Indonesia (Persero) which is 3 (three) hours from the time the customer reports the disturbance through the 021-147 reporting channel, the Plaza Telkom office, and the Indihome social media, untilthe disruption reporting ticket is closed. Table 2 shows the standard time for troubleshooting repairs.

Table 1. Service Level Agreement (SLA) – Fiber Optic Attenuation Standard

KPI	Description	Formula	Explanation
Q-TECHNICAL DISORDER	Percentage of interrupted customers within 30 days (technical tickets) of the total LIS of active and billed customers	$\frac{Customer\ Unit\ (Technical\ Open\ Ticket)}{LIS\ Fibe\ Billed}$	Include: Technical ticket Regular and Gamas Children FCR Solver (ROC, DSO, TVV) FCR Frontliner (Case Not Close) Ticket Status Open Excludes : FCR Frontliner (Case Closed) Force Majeur
ASSURANCE GUARANTEE	Percentage of uninterrupted customers > 1x (re-disruption) in the last 60 days to the number of closed customer interruptions (30 days) observation	$100\% - \frac{Disruption\ Customer > 1x}{Customer\ Disruption\ Closed}$	
UNDERSPECT ALL	Unspect customer ratio with LIS for all segments	$\frac{Unspect\ Customer}{LIS\ Fiber\ Billed}$	Unspec Non Warranty with measuring results less than -25 dBm and above – 10 dBm LIS (Billed Fiber) all segment

Source : PT. Telkom Indonesia (Persero)

Table 2. Service Level Agreement (SLA) – Standard Time for Repairs

KPI	Description	Formula
TTR COMPLY – 3 hours	The number of customers reporting disturbances (all technical tickets) completed in less than and equal to 3 hours calculated starting from open tickets (report customers), to all customers.	$\frac{TTR\ All\ Teknis \leq 3\ Jam}{All\ Tiket}$
TTR COMPLY – 3 hours HVC PLATINUM & GOLD	The number of HVC Platinum & Gold customers reported disturbances (all technical tickets) completed in less than and equal to 3 hours calculated starting from the open ticket (customer report).	$\frac{TTR\ All\ Teknis_{Plat_{Gold}} \leq 3\ Jam}{All\ Tiket\ HVC}$

Source : PT. Telkom Indonesia (Persero)

2.3. Fiber Optic

Internet networks using fiber optic cables are the main choice for the community, especially government agencies and companies [23]. Fiber optic is a type of cable made of glass or very fine plastic (120 micrometers

in diameter), used as a transmission medium. Fiber optic cables can transmit light signals at high speeds because their working principle uses light refraction, which is sourced from LEDs or LDs [24]. There are many advantages offered by fiber optic cable so that it can attract the interest of many people. The following are the advantages of fiber optic cables that are considered to be chosen, namely: 1) Having a large capacity, fiber optic cables are capable of delivering data with a capacity of up to gigabytes/second. In addition, the long and free transmission mileage determines the high bandwidth; 2) Thin/small components, fiber optic cable has a finer fiber when compared to a strand of hair which allows the availability of a large enough space; 3) Do not use electric current, this is considered to increase security because of the risk of short circuit and ensure that the fiber optic cable does not experience interference from electromagnetic signals and radio signals; 4) Data validation is guaranteed because it has a high data access speed, it is unlikely that data loss will occur when using fiber optic cables [23]. However, fiber optic cable also has weaknesses, namely: 1) Requires large costs, ranging from materials, installation costs, and maintenance; and 2) The installation is a bit complicated because usually fiber optic cables are installed on bended lines or have curved corners. One of the FTTH-based technologies is the Gigabit Capable Passive Optical Network (GPON) which can provide multimedia services such as voice, data, video, and others for residential and business customers [6]. The following in Fig. 2 details the architecture and topology of GPON.

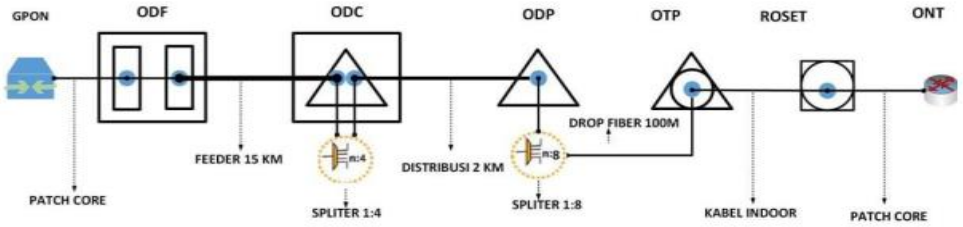

Fig. 2. Architecture and Topology of GPON [6]

The GPON architecture consists of several components, including: a) Optical Distribution Frame (ODF) which is a device for the initial termination of fiber optic cables and as a transition from outdoor cables to indoor cables or vice versa which acts as an intermediary between GPON and ODC; b) Optical Distribution Cabinet (ODC) which is a place for installing fiber optic networks and connecting feeder and distribution cables; c) Optical Distribution Point (ODP) which is a cable termination place that has corrosion resistance and weather resistance. The function of the ODP itself is also a liaison between ODC to OTP from the distribution cable to the drop cable whose contents are 1:8 to 1:16 branch optical cables depending on the capacity; d) Optical Termination Point (OTP) and Rosette are passive devices that are placed and affixed to the wall of the customer's house, as a place for cable termination at the customer's side and a connection point between drop cables from ODP and fiber optic cables. There are OTPs that have port capacities 1, 2, and 4. The contents of the OTP are fiber optic cables without wires and the output will go to the Rosette which is the connecting place between the optical indoor cable and the optical cable direction CPE in the form of ONT/ONU (Optical Network Terminal); e) Optical Network Terminal (ONT), placed at the subscriber which functions to receive optical traffic, convert traffic into data, voice, and video which is only used for fiber technology.

2.4. Fuzzy Logic

The fuzzy system is a structured and dynamic numerical estimator, perfect for mapping an input space into an output space. This system has the ability to develop intelligence systems in an uncertain environment, predicts a function with fuzzy logic [25]. In fuzzy logic there are several processes, namely the determination of the fuzzy set, the application of the IF-THEN rules and the fuzzy inference process. For very complex systems, the use of fuzzy logic is one solution [26]. Traditional systems are designed to control a single output from multiple unrelated inputs. Because of this independence, adding new inputs complicates the control process and requires recalculation of all functions [27], [28]. On the other hand, adding new inputs to a fuzzy system, which is a system that works based on the principles of fuzzy logic, only requires the addition of a new membership function and the rules associated with it. In general, fuzzy systems are very suitable for approach reasoning, especially for systems that deal with problems that are difficult to define using a mathematical model. For example, the input values and parameters of a system are less accurate or unclear, making it difficult to define the mathematical model [29], [30]. The fuzzy system has several advantages when compared to traditional systems, for example in the number of rules used. The initial processing of a large number of values

into a membership degree value in the fuzzy system reduces the number of values to a membership degree value in the fuzzy system, reducing the number of values that the controller must use to make a decision. Another advantage is that fuzzy system have reasoning abilities similar to human reasoning abilities. This is because the fuzzy system has the ability to respond based on information that is qualitative, inaccurate, and ambiguous. There are several methods to represent fuzzy logic results, namely the Tsukamoto, Sugeno and Mamdani methods. In the Tsukamoto method, each consequence is represented by a fuzzy set with a monotonic membership function. The output of the inference of each rule is z, in the form of a regular set (crisp) which is determined based on its -predicate. The final result is obtained using the weighted average [31], [32]. The Sugeno method is similar to the Mamdani method, only the output (consequent) is not a fuzzy set, but a constant or a linear equation [33], [34]. The equation used to determine the fuzzy set is :

$$\mu[\boldsymbol{Fuzzy\ Set}] = \begin{cases} 0 & ;x \leq b \\ \dfrac{b-x}{b-a} & ;a \leq x \leq b \\ 1 & ;x \leq a \end{cases} \quad (1)$$

In the mamdani method, the application of the implication function uses the MIN method, while the composition of the rules uses the MAX method. The mamdani method is also known as the MAX-MIN method. The resulting inference output in the form of fuzzy numbers must be determined a certain crisp value as output. This process is known as defuzzification. To more easily understand the stages of mamdani fuzzy logic, it can be seen in Fig. 3.

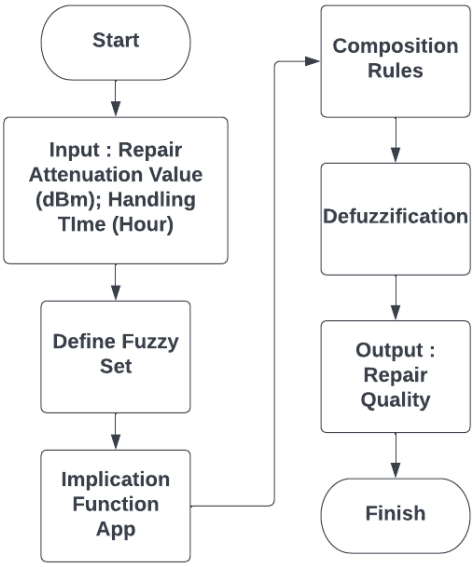

Fig. 3. Fuzzy Mamdani Logic

There are several stages to get the output, namely [35], [36]: 1) Formation of fuzzy sets, in the mamdani method both input and output variables are divided into one or more fuzzy sets; 2) Application of the implication function, in the mamdani method, the implication function used is MIN; 3) Rule composition, unlike monotonic reasoning, if the system consists of several rules, then inference is obtained from the collection and correlation between rules; 4) Defuzzification, the input of the defuzzification process is a fuzzy set obtained from the composition of fuzzy rules, while the resulting output is a number in the domain of the fuzzy set. So if given a fuzzy set within a certain range, it must be able to take a certain crisp value as output.

3. RESULTS AND DISCUSSION

This study uses a quantitative method, in which the author obtains a summary of customer data from PT. Telkom Indonesia in a period of 4 months of observation from August to November 2021. In August there were 776 customers, in September there were 362 customers, in October there were 359 customers, and in November 445 customers who underwent Indihome fiber optic cable maintenance, based on attenuation (dB) measurement from an Optical Power Meter (OPM). The data can be seen in Table 3.

Table 3. IndiHome Internet Network Report

Number	Ticket ID	Disturbance Month	Reported Date	Attenuation (dB)	Handling Time (Hour)
1	IN105830977	August	01-08-2021	18.39	2.951667
2	IN105831081	August	01-08-2021	0	2.961944
3	IN105833978	August	01-08-2021	18.47	2.962778
4	IN105848630	August	01-08-2021	18.76	0.950833
5	IN105858678	August	01-08-2021	26.94	1.951111
6	IN108829590	September	01-09-2021	17.09	4.617500
7	IN108831725	September	01-09-2021	18.3	4.626389
8	IN108832610	September	01-09-2021	14.5	1.431389
9	IN108834427	September	01-09-2021	19.91	4.627778
10	IN108845281	September	01-09-2021	18.24	2.302222
11	IN111501700	October	01-10-2021	18.47	2.482778
12	IN111503515	October	01-10-2021	22.92	1.546389
13	IN111506988	October	01-10-2021	17.19	11.175278
14	IN111508387	October	01-10-2021	19.33	11.325556
15	IN111509846	October	01-10-2021	25.22	2.483889
16	IN115118257	November	01-11-2021	0	2.710000
17	IN115196557	November	01-11-2021	23.56	1.740556
18	IN115197203	November	01-11-2021	20.6	2.711389
19	IN115216236	November	01-11-2021	0	15.058056
20	IN115257496	November	01-11-2021	22.83	2.712222

3.1. Define Fuzzy Set

Data processing is done by determining the variables and universe of discussion, then proceed with forming fuzzy sets. Determination of variables and universe of discussion from available research data, can be seen in Table 4, Table 5, and Table 6.

Table 4. Handling Time

Membership Function (Hour) : [0 – 3]	
Time	**Domain (Hour)**
Fast	0-1
Normal	1-2
Slow	2-3

Table 5. Attenuation

Membership Function (dB) : [10 - 30]	
Attenuation	**Domain (dB)**
Low	10-20
Normal	15-25
High	20-30

Table 6. Repair Quality

Membership Function: [1 – 10]	
Repair Results	**Domain**
Very good	7-10
Good	4-7
Bad	1-3

3.2 Implication Function App

The next step is to create a membership function for each Handling Time variable. The membership function of the variable Handling Time includes a triangular shape curve. This can be seen in Fig. 4. Membership Function Variable "Attenuation" show in Fig. 5. Membership Function Variable "Repair Quality" show in Fig. 6.

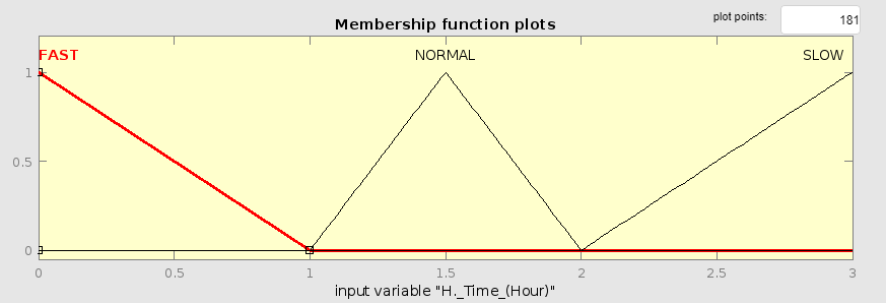

Fig. 4. Membership Function Variable "Handling Time"

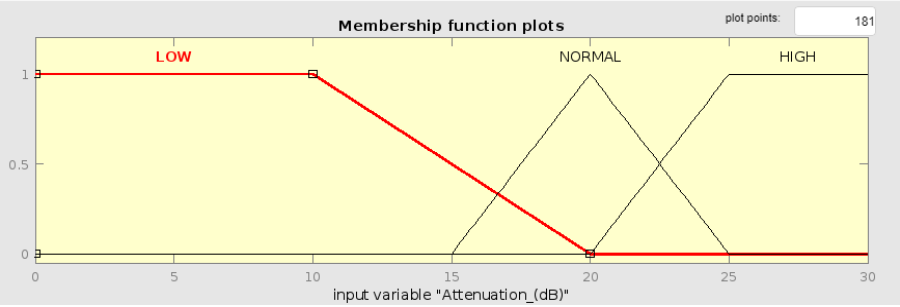

Fig. 5. Membership Function Variable “Attenuation”

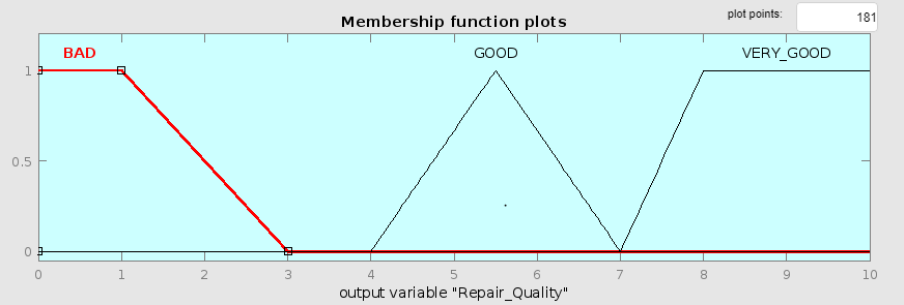

Fig. 6. Membership Function Variable “Repair Quality”

3.3 Composition Rules

Next is the formation of fuzzy logic rules. Several rules that can be formed based on the available data, namely:

1. If (H. Time is FAST) and (Attenuation is LOW) then (Repair Quality is VERY GOOD)
2. If (H. Time is NORMAL) and (Attenuation is LOW) then (Repair Quality is GOOD)
3. If (H. Time is SLOW) and (Attenuation is LOW) then (Repair Quality is BAD)
4. If (H. Time is FAST) and (Attenuation is NORMAL) then (Repair Quality is VERY GOOD)
5. If (H. Time is NORMAL) and (Attenuation is NORMAL) then (Repair Quality is GOOD)
6. If (H. Time is SLOW) and (Attenuation is NORMAL) then (Repair Quality is BAD)
7. If (H. Time is FAST) and (Attenuation is HIGH) then (Repair Quality is VERY GOOD)
8. If (H. Time is NORMAL) and (Attenuation is HIGH) then (Repair Quality is GOOD)
9. If (H. Time is SLOW) and (Attenuation is HIGH) then (Repair Quality is BAD)

3.4 Defuzzification

The last step is affirmation (defuzzification).There are several methods used in defuzzification, namely [37], [38]: 1) Centroid method, in this method the determination of the crisp value by taking the center point of the fuzzy area; 2) The Bisector Method, in this method, the crisp solution is obtained by taking a value in the fuzzy domain which has a membership value such as from the total number of membership values in the

fuzzy area; 3) The Means of Maximum (MOM) method, in this method, the crisp solution is obtained by taking the average value of the domain that has the maximum membership value; 4) The Largest of Maximum (LOM) method, in this method, the crisp solution is obtained by taking the largest value from the domain that has the maximum membership value; 5) The Smallest of Maximum (SOM) method, the crisp solution is obtained by taking the smallest value from the domain that has the maximum membership value. The fuzzy reasoning used in this study uses the centroid method which is described in Fig. 7. The test results with the centroid method with an input Handling Time of 1.5 hours and an Attenuation of 15 dB, then the output Repair Quality is 5.5 or categorized as Good.

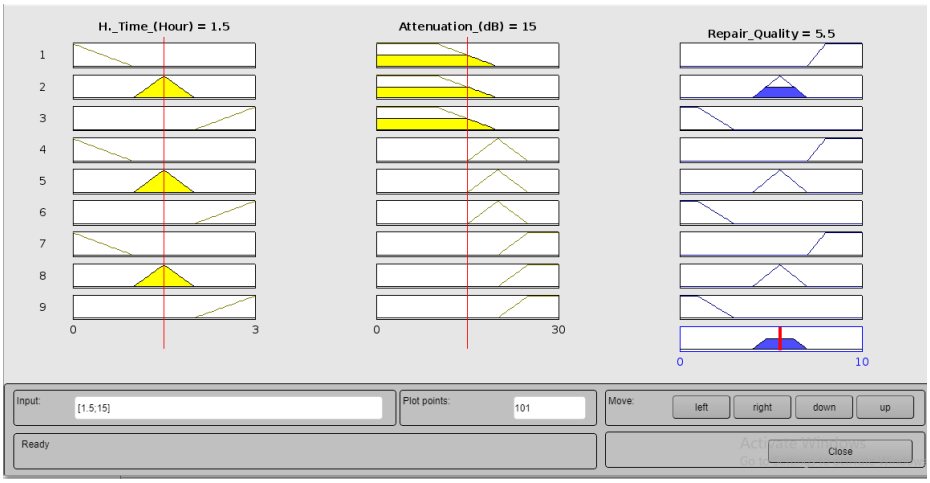

Fig. 7. Defuzzification

4. CONCLUSION

Based on the results of an analysis of the quality classification of internet disturbance repairs in the Gambir area, West Jakarta using Mamdani fuzzy logic, it can be concluded that within 4 months of observation there were 1942 IndiHome internet disturbances, which were resolved in accordance with the Service Level Agreement (SLA) set by PT. Telkom Indonesia (Persero), which is a maximum repair of 3 hours with a minimum attenuation of 13 dBm and a maximum of 24 dBm. From the results of the mamdani fuzzy logic classification, it is able to provide decisions through determining fuzzy sets, applying the implication function of IF-THEN rules using the MIN method, and composition rules using the MAX method, as well as the fuzzy inference process by determining certain firm values as output via the centroid method. In general, fuzzy systems are very suitable for reasoning approaches, especially for systems that deal with problems that are difficult to define using mathematical models. Fuzzy systems have several advantages when compared to traditional systems, for example in the number of rules used. Another advantage is that fuzzy systems have reasoning abilities that are similar to human reasoning abilities. This is because the fuzzy system has the ability to respond based on information that is qualitative, inaccurate, and ambiguous.

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REFERENCES

[1] H. A. Bany Salameh, S. Almajali, M. Ayyash and H. Elgala, "Spectrum Assignment in Cognitive Radio Networks for Internet-of-Things Delay-Sensitive Applications Under Jamming Attacks," *in IEEE Internet of Things Journal*, vol. 5, no. 3, pp. 1904-1913, 2018, https://doi.org/10.1109/JIOT.2018.2817339.

[2] B. Mao, Y. Kawamoto and N. Kato, "AI-Based Joint Optimization of QoS and Security for 6G Energy Harvesting Internet of Things," *in IEEE Internet of Things Journal*, vol. 7, no. 8, pp. 7032-7042, 2020, https://doi.org/10.1109/JIOT.2020.2982417.

[3] A. Wiraguna, P. Komarodin and I. Budi, "Twitter Sentiment Analysis of Indonesia Internet Service Provider: A Case Study of Indihome and Firstmedia," *2021 International Conference on Computer Science and Engineering (IC2SE),*

vol. 1, pp. 1-6, 2021, https://doi.org/10.1109/IC2SE52832.2021.9791971.
[4] M. K. Hernandi, S. A. Wibowo and S. Suyanto, "Sentiment Analysis Implementation For Detecting Negative Sentiment Towards Indihome In Twitter Using Bidirectional Long Short Term Memory," *2021 IEEE International Conference on Industry 4.0, Artificial Intelligence, and Communications Technology (IAICT)*, pp. 143-147, 2021, https://doi.org/10.1109/IAICT52856.2021.9532546.
[5] P. S. Cherpak, R. I. Shaidullin and O. A. Ryabushkin, "Measurement of Laser Radiation Attenuation in Metallized Optical Fibers in Visible and Near-IR Spectral Ranges," *2020 International Conference Laser Optics (ICLO)*, pp. 1-1, 2020, https://doi.org/10.1109/ICLO48556.2020.9285567.
[6] J. Hayes, *Fiber Optics Technician's Manual 2nd Edition*, 2nd ed. Delmar Cengage Learning, 2020, https://books.google.co.id/books?id=ECy8ulPSbTQC.
[7] S. Budiyanto and I. Pratama, "Classification of Network Status in Academic Information Systems using Naive Bayes Algorithm Method," *2020 2nd International Conference on Broadband Communications, Wireless Sensors and Powering (BCWSP)*, pp. 107-112, 2020, https://doi.org/10.1109/BCWSP50066.2020.9249398.
[8] T. Hidayat and M. Alaydrus, "Performance Analysis and Mitigation of Virtual Machine Server by using Naive Bayes Classification," *2019 Fourth International Conference on Informatics and Computing (ICIC)*, pp. 1-5, 2019, https://doi.org/10.1109/ICIC47613.2019.8985932.
[9] S. Wang, J. Ren and R. Bai, "A Regularized Attribute Weighting Framework for Naive Bayes," *in IEEE Access*, vol. 8, pp. 225639-225649, 2020, https://doi.org/10.1109/ACCESS.2020.3044946.
[10] R. Hermansyah and R. Sarno, "Sentiment Analysis about Product and Service Evaluation of PT Telekomunikasi Indonesia Tbk from Tweets Using TextBlob, Naive Bayes & K-NN Method," *2020 International Seminar on Application for Technology of Information and Communication (iSemantic)*, pp. 511-516, 2020, https://doi.org/10.1109/iSemantic50169.2020.9234238.
[11] S. Wang, J. Ren and R. Bai, "A Regularized Attribute Weighting Framework for Naive Bayes," *in IEEE Access*, vol. 8, pp. 225639-225649, 2020, https://doi.org/10.1109/ACCESS.2020.3044946.
[12] A. Fasanmade *et al.*, "A Fuzzy-Logic Approach to Dynamic Bayesian Severity Level Classification of Driver Distraction Using Image Recognition," *in IEEE Access*, vol. 8, pp. 95197-95207, 2020, https://doi.org/10.1109/ACCESS.2020.2994811.
[13] A. T. Khomeiny, T. Restu Kusuma, A. N. Handayani, A. Prasetya Wibawa and A. H. Supadmi Irianti, "Grading System Recommendations for Students using Fuzzy Mamdani Logic," *2020 4th International Conference on Vocational Education and Training (ICOVET)*, pp. 1-6, 2020, https://doi.org/10.1109/ICOVET50258.2020.9230299.
[14] M. Abdulgader and D. Kaur, "Evolving Mamdani Fuzzy Rules Using Swarm Algorithms for Accurate Data Classification," *in IEEE Access*, vol. 7, pp. 175907-175916, 2019, https://doi.org/10.1109/ACCESS.2019.2957735.
[15] F. Es-Sabery, A. Hair, J. Qadir, B. Sainz-De-Abajo, B. García-Zapirain and I. D. L. Torre-Díez, "Sentence-Level Classification Using Parallel Fuzzy Deep Learning Classifier," *in IEEE Access*, vol. 9, pp. 17943-17985, 2021, https://doi.org/10.1109/ACCESS.2021.3053917.
[16] W. B. Zulfikar, Jumadi, P. K. Prasetyo, and M. A. Ramdhani, "Implementation of Mamdani Fuzzy Method in Employee Promotion System," *in IOP Conference Series: Materials Science and Engineering*, vol. 288, no. 1, p. 012147, 2018, https://doi.org/10.1088/1757-899X/288/1/012147.
[17] R. F. Ningrum, R. R. A. Siregar, D. Rusjdi, "Fuzzy mamdani logic inference model in the loading of distribution substation transformer SCADA system," *IAES Int. J. Artif. Intell. (IJ-AI)*, vol. 10, no. 2, pp. 298–305, 2021, http://doi.org/10.11591/ijai.v10.i2.pp298-305.
[18] S. Moedjiono, Suhaemi and A. Kusdaryono, "Critical Server Determination using Fuzzy Mamdani and Fuzzy Sugeno Methods," *2019 Fourth International Conference on Informatics and Computing (ICIC)*, pp. 1-7, 2019, https://doi.org/10.1109/ICIC47613.2019.8985964.
[19] M. Silvana, R. Akbar, Derisma, M. Audina and Firdaus, "Development of Classification Features of Mental Disorder Characteristics Using The Fuzzy Logic Mamdani Method," *2018 International Conference on Information Technology Systems and Innovation (ICITSI)*, pp. 410-414, 2018, https://doi.org/10.1109/ICITSI.2018.8696043.
[20] A. Arifianto *et al.*, "Developing an LSTM-based Classification Model of IndiHome Customer Feedbacks," *2020 International Conference on Data Science and Its Applications (ICoDSA)*, pp. 1-5, 2020, https://doi.org/10.1109/ICoDSA50139.2020.9212863.
[21] D. H. L. Oliveira, F. M. V. Filho, T. P. de Araújo, J. Celestino and R. L. Gomes, "Adaptive Model for Network Resources Prediction in Modern Internet Service Providers," *2020 IEEE Symposium on Computers and Communications (ISCC)*, pp. 1-6, 2020, https://doi.org/10.1109/ISCC50000.2020.9219550.
[22] T.-H. Chen, R. C. Hsiao, T.-L. Liu, C.-F. Yen, "Predicting effects of borderline personality symptoms and self-concept and identity interruptions on internet addiction, depression, and suicidality in college students: A prospective study," *Kaohsiung J. Med. Sci.*, vol. 35, no. 8, pp. 508–514, 2019, https://doi.org/10.1002/kjm2.12082.
[23] N. Guo, S. K. Bose, B. Mukherjee and G. Shen, "Impact of Fiber Attenuation and Effective Area on Spectrum Efficiency of Elastic Optical Networks," *in Journal of Lightwave Technology*, vol. 40, no. 8, pp. 2200-2213, 2022, https://doi.org/10.1109/JLT.2021.3136574.
[24] H. Zhang, Z. Liu, Z. Yuan, W.Gao, Y. Dong, "A liquid-level sensing system based on high attenuation fiber and DPP-BOTDA," *in 25th Optical Fiber Sensors Conference (OFS)*, pp. 1-4, 2017, https://doi.org/10.1117/12.2263958.
[25] S. P. Cherniy, A. V. Buzikayeva and A. S. Gudim, "A Model of Multi-Cascade Fuzzy Logic Controller Implemented Using Different Variations of Inference Algorithms," *2019 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)*, pp. 1-4, 2019, https://doi.org/10.1109/FarEastCon.2019.8934872.

[26] D. Sahid and M. Alaydrus, "Multi Sensor Fire Detection in Low Voltage Electrical Panel Using Modular Fuzzy Logic," *2020 2nd International Conference on Broadband Communications, Wireless Sensors and Powering (BCWSP)*, pp. 31-35, 2020, https://doi.org/10.1109/BCWSP50066.2020.9249400.
[27] I. O. Olayode, L. K. Tartibu and M. O. Okwu, "Application of Fuzzy Mamdani Model for Effective Prediction of Traffic Flow of Vehicles at Signalized Road Intersections," *2021 IEEE 12th International Conference on Mechanical and Intelligent Manufacturing Technologies (ICMIMT)*, pp. 219-224, 2021, https://doi.org/10.1109/ICMIMT52186.2021.9476201.
[28] S. Wen, S. Xiao, Y. Yang, Z. Yan, Z. Zeng and T. Huang, "Adjusting Learning Rate of Memristor-Based Multilayer Neural Networks via Fuzzy Method," *in IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, vol. 38, no. 6, pp. 1084-1094, 2019, https://doi.org/10.1109/TCAD.2018.2834436.
[29] F. Es-Sabery, I. Es-Sabery, A. Hair, B. Sainz-De-Abajo and B. Garcia-Zapirain, "Emotion Processing by Applying a Fuzzy-Based Vader Lexicon and a Parallel Deep Belief Network Over Massive Data," *in IEEE Access*, vol. 10, pp. 87870-87899, 2022, https://doi.org/10.1109/ACCESS.2022.3200389.
[30] J. M. Leski, R. Czabański, M. Jezewski and J. Jezewski, "Fuzzy Ordered c-Means Clustering and Least Angle Regression for Fuzzy Rule-Based Classifier: Study for Imbalanced Data," *in IEEE Transactions on Fuzzy Systems*, vol. 28, no. 11, pp. 2799-2813, 2020, https://doi.org/10.1109/TFUZZ.2019.2939989.
[31] G. Selvachandran *et al.*, "A New Design of Mamdani Complex Fuzzy Inference System for Multiattribute Decision Making Problems," *in IEEE Transactions on Fuzzy Systems*, vol. 29, no. 4, pp. 716-730, 2021, https://doi.org/10.1109/TFUZZ.2019.2961350.
[32] F. Topaloğlu and H. Pehlıvan, "Comparison of Mamdani type and Sugeno type fuzzy inference systems in wind power plant installations," *2018 6th International Symposium on Digital Forensic and Security (ISDFS)*, pp. 1-4, 2018, https://doi.org/10.1109/ISDFS.2018.8355384.
[33] L. M. Silalahi, S. Budiyanto, I. U. V. Simanjuntak, F. A. Silaban, A. D. Rochendi and W. A. Karimah, "Real-Time Examination System For New Students At Pandemic Time Covid 19 Using Fuzzy Logic," *2021 IEEE International Conference on Communication, Networks and Satellite (COMNETSAT)*, pp. 219-224, 2021, https://doi.org/10.1109/COMNETSAT53002.2021.9530832.
[34] S. Budiyanto, L. Medriavin Silalahi, F. Artadima Silaban, U. Darusalam, S. Andryana and I. M. Fajar Rahayu, "Optimization Of Sugeno Fuzzy Logic Based On Wireless Sensor Network In Forest Fire Monitoring System," *2020 2nd International Conference on Industrial Electrical and Electronics (ICIEE)*, pp. 126-134, 2020, https://doi.org/10.1109/ICIEE49813.2020.9277365.
[35] G. Johann, C. S. dos Santos, P. F. Montanher, R. A. Paes de Oliveira and A. C. Carniel, "Applying Fuzzy Inference Systems in the Extraction of Chia Cake Extract: Predicting the Mass Yield," *2021 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE)*, pp. 1-6, 2021, https://doi.org/10.1109/FUZZ45933.2021.9494541.
[36] A. Najmurrokhman, Kusnandar, U. Komarudin, Sunubroto, A. Sadiyoko and T. Y. Iskanto, "Mamdani based Fuzzy Logic Controller for A Wheeled Mobile Robot with Obstacle Avoidance Capability," *2019 International Conference on Mechatronics, Robotics and Systems Engineering (MoRSE)*, pp. 49-53, 2019, https://doi.org/10.1109/MoRSE48060.2019.8998720.
[37] T. Wei, H. Yongjiang, Z. Yuefei, L. Wenguang and Z. Xiaomeng, "Multi-UAV Task Allocation Based on Type Mamdani Fuzzy Logic," *2021 7th International Symposium on Mechatronics and Industrial Informatics (ISMII)*, pp. 184-187, 2021, https://doi.org/10.1109/ISMII52409.2021.00046.
[38] T. V. Alekseychik, T. V. Bogachev, D. N. Karasev, L. V. Sakharova and M. B. Stryukov, "Fuzzy Method of Assessing the Intensity of Agricultural Production on a Set of Criteria of the Level of Intensification and the Level of Economic Efficiency of Intensification," *International Conference on Theory and Applications of Fuzzy Systems and Soft Computing*, pp. 635-642, 2018, https://doi.org/10.1007/978-3-030-04164-9_83.

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