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Tsukamoto Fuzzy Logic Method for Determining Mental Health Levels of Final-Year University Students

Nabila Rizky Sarip
Department of Computer Science
State Islamic University of North Sumatera, Indonesia
nabilasaarip08@gmail.com

Sriani Sriani
Department of Computer Science
State Islamic University of North Sumatera, Indonesia
sriani@uinsu.ac.id

Abstract-Mental health is an important aspect that affects the ability of final-semester students to complete their studies and face academic and non-academic pressures. The problem that arises is the difficulty in assessing mental health conditions because it is subjective and complex. The Tsukamoto fuzzy method is used because it is able to handle data uncertainty and provides results in the form of measurable crisp values. This study aims to apply the Tsukamoto fuzzy logic method in determining the level of mental health of final-semester students in a more objective and measurable manner. This system model uses four input variables, namely stress level, sleep quality, emotional exhaustion, and duration of gadget use, with 81 rules (rule base) that form relationships between variables. The inference process is carried out through the stages of fuzzification, rule inference, and defuzzification with increasing and decreasing linear triangular membership functions. Testing was carried out using MATLAB by comparing the prediction results to actual data to calculate the model accuracy level using the Mean Absolute Percentage Error (MAPE). The results showed that the total MAPE value was 19.34%, which is in the range of 10%–20% so it is included in the good accuracy category. This demonstrates that the Tsukamoto fuzzy method can provide fairly accurate predictions of the mental health of final-semester students. Therefore, this system can be used as a tool for evaluating and early detection of student mental health in higher education settings.

Keywords —Tsukamoto Fuzzy Logic, Mental Health, Final-Year Students

I. INTRODUCTION

Mental health is a crucial aspect that influences the ability of final-semester students to cope with academic, social, and emotional pressures[1]. The pressures of completing final assignments, the uncertainty of the future, and environmental demands often lead to psychological disorders such as stress, anxiety, and depression[2], which impact both academic performance and personal well-being[3]. Assessing students' mental health presents a unique challenge due to its complex and subjective nature[4].

To address this complexity, the application of artificial intelligence-based methods such as fuzzy logic offers an effective alternative[5]. Fuzzy logic is an approach capable of

handling vague and uncertain data[6], making it suitable for assessing psychological conditions that do not always have a clear boundary between healthy and unhealthy[7]. One variant of this method is the Tsukamoto Fuzzy Inference System (FIS)[8], which has the advantage of producing crisp output, making analysis results more measurable and objective[9].

This study applies the Tsukamoto fuzzy logic method to determine the mental health of final-semester students by considering four main variables: stress level, sleep quality, emotional exhaustion, and duration of gadget use[10]. Through fuzzification, inference, and defuzzification stages[11], this system is expected to be able to identify students' mental health conditions more accurately[12]. Previous research has shown that the Tsukamoto fuzzy logic method can be used effectively to detect anxiety and depression levels in students with an accuracy rate above 75%[13].

This research is expected to create a mental health assessment system that is not only evaluative but can also be used as a tool for educational institutions in the early detection of mental disorders in students[14]. Furthermore, this research also contributes to expanding the application of fuzzy logic methods in the fields of educational psychology and mental health, particularly in higher education settings[15].

II. RELATED WORKS

This research employed a quantitative approach utilizing Tsukamoto fuzzy logic computation. The first stage was problem identification, followed by data collection techniques. The data used in this study were final-semester computer science students obtained from questionnaires distributed to final-year students at the State Islamic University of North Sumatra. The data consisted of 50 respondents. Data were collected through questionnaires, observations to assess the students' general condition, and literature to support the theoretical analysis of fuzzy logic and psychological aspects. The fuzzy system model design consisted of four input variables and one output: stress level, sleep quality, emotional exhaustion, duration of gadget use, and mental health.

A. Data Analysis Techniques

The data analysis technique was carried out using the Tsukamoto fuzzy method, which includes the first stage of fuzzification, converting crisp values (respondent data) into degrees of collection for each variable using the triangle collection function (triangle)[16].

The following table shows the membership functions for each variable:

Table 1. Fuzzy Set

function	Variables	Fuzzy Set	Range	Domain
Input	Stress Level	Low	[0-100]	[0 30 50]
		Medium	[0-100]	[30 50 75]
		High	[0-100]	[50 75 100]
	Sleep Quality	Bad	[0-100]	[0 30 50]
		Enough	[0-100]	[30 50 75]
		Good	[0-100]	[50 75 100]
	Emotional Exhaustion	Low	[0-100]	[0 30 50]
		Medium	[0-100]	[30 50 75]
		High	[0-100]	[50 75 100]
	Duration of	Low	[0-100]	[0 30 50]

	Gadget Use	Medium	[0-100]	[30 50 75]
		High	[0-100]	[50 75 100]
Output	Mental Health	Bad	[0-100]	[0 30 50]
		Medium	[0-100]	[30 50 75]
		Good	[0-100]	[50 75 100]

Table 1. shows the domains obtained from each input and output variable.

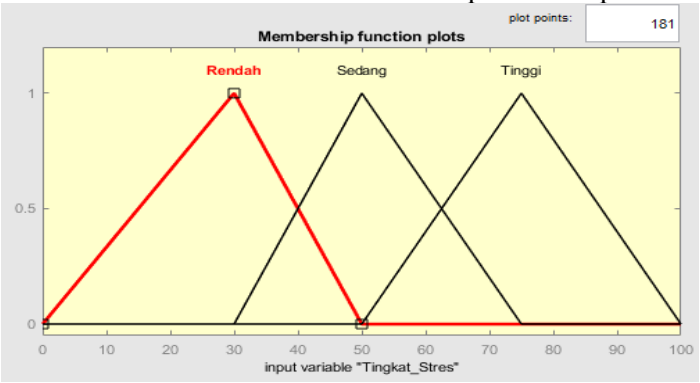

Figure 1. Membership function curve of the Stress Level variable

In the membership function curve of the stress level variable, there are three conditions and they can be formulated:

Low stress levels

$$\mu\ Low(x) = \begin{cases} 0 & x \le 0 \text{ or } x \ge 50 \\ \dfrac{x-0}{30-0} & 0 \le x \le 30 \text{ (ups)} \\ & 30 \le x \le 50 \text{ (down)} \\ \dfrac{50-x}{50-30} & \end{cases}$$

Low stress level [0 30 50]

Medium stress levels

$$\mu\ Medium(x) = \begin{cases} 0 & x \le 30 \text{ or } x \ge 75 \\ \dfrac{x-30}{50-30} & 30 \le x \le 50 \text{ (ups)} \\ & 50 \le x \le 75 \text{ (down)} \\ \dfrac{75-x}{75-50} & \end{cases}$$

Medium stress level [30 50 75]

High stress levels

$$\mu\ Medium(x) = \begin{cases} 0 & x \le 50 \text{ or } x \ge 100 \\ \dfrac{x-50}{75-50} & 30 \le x \le 75 \text{ (ups)} \\ & 50 \le x \le 75 \text{ (down)} \\ \dfrac{100-x}{100-75} & \end{cases}$$

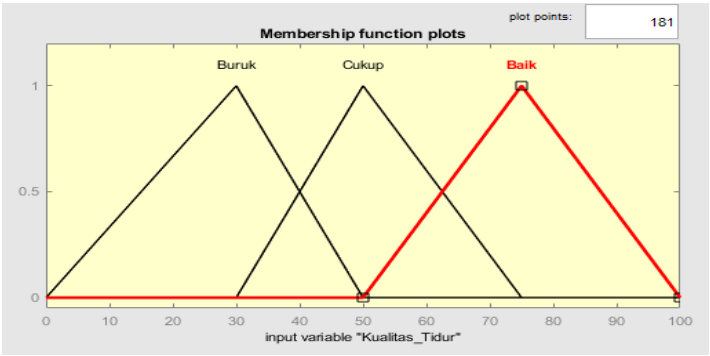

Figure 2. Membership function curve of the Sleep Quality variable

In the membership function curve of the sleep quality variable, there are three conditions and they can be formulated as follows:

Bad Sleep Quality

$$\mu\ Bad(x) = \begin{cases} 0 & x \le 0 \text{ or } x \ge 50 \\ \dfrac{x-0}{30-0} & 0 \le x \le 30 \text{ (ups)} \\ & 30 \le x \le 50 \text{ (down)} \\ \dfrac{50-x}{50-30} & \end{cases}$$

Bad Sleep Quality [0 30 50]

Enough Sleep Quality

$$\mu\ Enough(x) = \begin{cases} 0 & x \le 30 \text{ or } x \ge 75 \\ \dfrac{x-30}{50-30} & 30 \le x \le 50 \text{ (ups)} \\ & 50 \le x \le 75 \text{ (down)} \\ \dfrac{75-x}{75-50} & \end{cases}$$

Enough Sleep Quality [30 50 75]

Good Sleep Quality

$$\mu\ Good(x) = \begin{cases} 0 & x \le 50 \text{ or } x \ge 100 \\ \dfrac{x-30}{75-50} & 50 \le x \le 50 \text{ (ups)} \\ & 50 \le x \le 75 \text{ (down)} \\ \dfrac{100-x}{100-75} & \end{cases}$$

Good Sleep Quality [50 75 100]

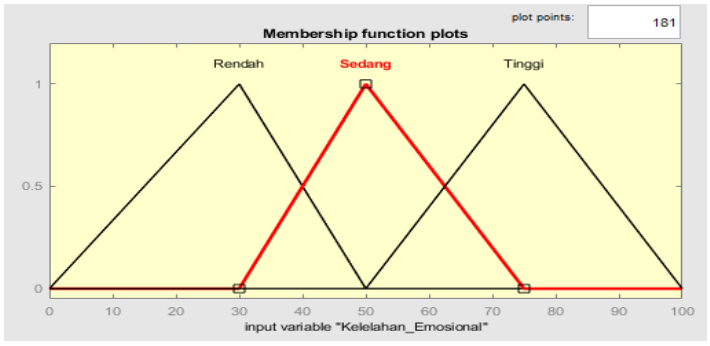

Figure 3. Membership function curve of the Emotional Exhaustion variable

In the membership function curve of the emotional exhaustion variable, there are three conditions and they can be formulated as follows:

Low Emotional Exhaustion

$$\mu\ Low(x) = \begin{cases} 0 & x \le 0 \text{ or } x \ge 50 \\ \dfrac{x-0}{30-0} & 0 \le x \le 30 \text{ (ups)} \\ & 30 \le x \le 50 \text{ (down)} \\ \dfrac{50-x}{50-30} & \end{cases}$$

Low Emotional Exhaustion [0 30 50]

Medium Emotional Exhaustion

$$\mu\ Medium(x) = \begin{cases} 0 & x \le 30 \text{ or } x \ge 75 \\ \dfrac{x-30}{50-30} & 30 \le x \le 50 \text{ (ups)} \\ & 50 \le x \le 75 \text{ (down)} \\ \dfrac{75-x}{75-50} & \end{cases}$$

Medium Emotional Exhaustion [30 50 75]

High Emotional Exhaustion

$$\mu\ High(x) = \begin{cases} 0 & x \le 50 \text{ or } x \ge 100 \\ \dfrac{x-50}{75-50} & 50 \le x \le 75 \text{ (ups)} \\ \dfrac{100-x}{100-75} & 50 \le x \le 75 \text{ (down)} \end{cases}$$

High Emotional Exhaustion [50 75 100]

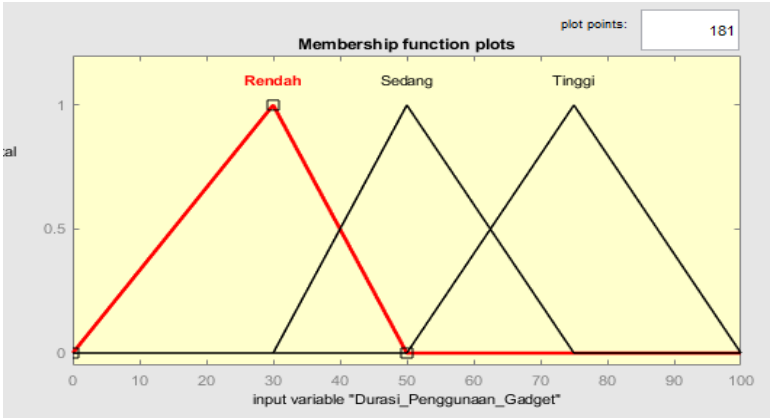

Figure 4. Membership function curve of the variable Duration of Gadget Use

In the membership function curve of the gadget usage duration variable, there are three conditions and they can be formulated as follows:

Low duration of gadget use

$$\mu\ Low(x) = \begin{cases} 0 & x \le 0 \text{ or } x \ge 50 \\ \dfrac{x-0}{30-0} & 0 \le x \le 30 \text{ (ups)} \\ & 30 \le x \le 50 \text{ (down)} \\ \dfrac{50-x}{50-30} & \end{cases}$$

Low duration of gadget use [0 30 50]

Medium duration of gadget use

$$\mu\ Medium(x) = \begin{cases} 0 & x \le 30 \text{ or } x \ge 75 \\ \dfrac{x-30}{50-30} & 30 \le x \le 50 \text{ (ups)} \\ & 50 \le x \le 75 \text{ (down)} \\ \dfrac{75-x}{75-50} & \end{cases}$$

Medium duration of gadget use [30 50 75]

High duration of gadget use

$$\mu\ High(x) = \begin{cases} 0 & x \le 50 \text{ or } x \ge 100 \\ \dfrac{x-50}{75-50} & 50 \le x \le 75 \text{ (ups)} \\ \dfrac{100-x}{100-75} & 50 \le x \le 75 \text{ (down)} \end{cases}$$

High duration of gadget use [50 75 100]

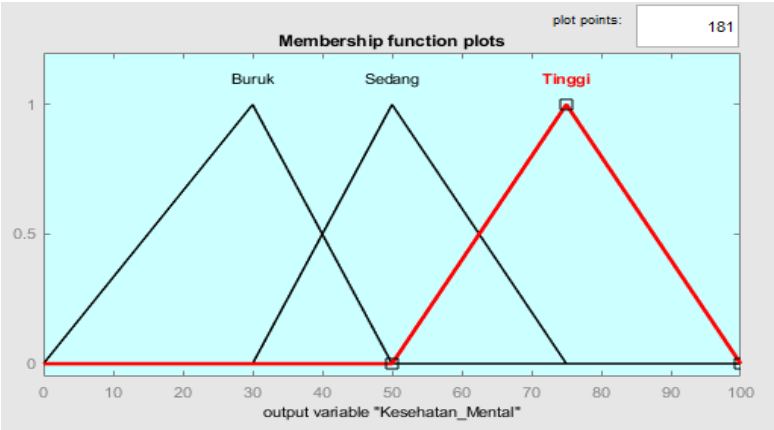

Figure 5. Mental Health Output

Describes the membership function curve of the mental health output variable. Each set of poor, average, and good uses a triangular function. The following is the formulation of the mental health membership function.

Bad Mental Health

$$\mu\ Low(x) = \begin{cases} 0 & x \le 0 \text{ or } x \ge 50 \\ \dfrac{x-0}{30-0} & 0 \le x \le 30 \text{ (ups)} \\ \dfrac{50-x}{50-30} & 30 \le x \le 50 \text{ (down)} \end{cases}$$

Low Mental Health [0 30 50]

Medium Mental Health

$$\mu\ Medium(x) = \begin{cases} 0 & x \le 30 \text{ or } x \ge 75 \\ \dfrac{x-30}{50-30} & 30 \le x \le 50 \text{ (ups)} \\ \dfrac{75-x}{75-50} & 50 \le x \le 75 \text{ (down)} \end{cases}$$

Medium Mental Health [30 50 75]

Good Mental Health

$$\mu\ High(x) = \begin{cases} 0 & x \le 50 \text{ or } x \ge 100 \\ \dfrac{x-50}{75-50} & 50 \le x \le 75 \text{ (ups)} \\ \dfrac{100-x}{100-75} & 50 \le x \le 75 \text{ (down)} \end{cases}$$

Good Mental Health [50 75 100]

B. Attribute Data

The data used in the fuzzy system inference process to determine the mental health level of final-semester students. Four input variables were used: stress level, sleep quality, emotional exhaustion, and duration of gadget use[17]. These five variables were selected from data collection conducted by distributing questionnaires to Computer Science students at the State Islamic University of North Sumatra. The questionnaire consisted of 15 questions as follows:

Table 2. Attribute Data

No	Question	Code
1.	I feel academically stressed because of the many assignments and exams in my major.	TS1
2.	I feel burdened by my final assignment or thesis.	TS2
3.	I often put off doing assignments until the deadline is near.	TS3
4.	I often feel overwhelmed by the demands of college.	TS4
5.	I feel anxious thinking about the future after graduation.	TS5
6.	I often sleep late at night even though there is no urgent need.	KT1
7.	I feel like my sleep time is not enough to make me fresh when I wake up.	KT2
8.	I get enough sleep every night (at least 6–8 hours).	KT3
9.	I have disturbed sleep due to stress or overthinking.	KT4
10.	I feel like I sleep soundly without waking up often at night.	KT5
11.	Have you been feeling irritable or irritated lately?	KE1

12.	How often do you feel like your brain is “full” and have difficulty concentrating?	KE2
13.	Do you feel emotionally empty or demotivated?	KE3
14.	Do you often feel sad without any clear reason?	KE4
15.	I feel unmotivated to carry out daily activities.	KE5
16.	I always spend an average of more than 8 hours/day in front of a gadget (cellphone/laptop)?	DPG1
17.	Does using gadgets interfere with your rest time?	DPG2
18.	Do you find it difficult to break away from using gadgets?	DPG3

Code description:
TS = Stress Level Variable
KT = Sleep Quality Variable
KE = Emotional Exhaustion Variable
DPG = Gadget Use Duration Variable

C. Data Characteristics

A total of 50 final-year undergraduate students participated in this study. To ensure ethical research practices and respondent confidentiality, individual identities were anonymized using respondent codes (User01–User50). The collected data represent students’ stress levels, sleep quality, emotional exhaustion, and duration of gadget use, obtained through a structured questionnaire.

Instead of presenting raw individual data, the results are summarized using descriptive statistical analysis to provide a clearer and more concise overview of respondent characteristics.

Table 3. Descriptive Statistics of Input Variables

Variable	Minimum	Maximum	Mean	Standard Deviation
Stress Level	35	95	69.4	13.2
Sleep Quality	40	90	70.1	11.5
Emotional Exhaustion	35	85	67.8	12.9
Gadget Use Duration	33.3	91.6	70.6	14.1

The descriptive statistical analysis shows that the average stress level of final-year students is relatively high, indicating significant academic and psychological pressure. Sleep quality and emotional exhaustion also demonstrate moderate to high mean values, suggesting that prolonged academic demands affect students’ rest and emotional conditions. Furthermore, the high average duration of gadget use reflects students’ dependence on digital devices, which may contribute to mental fatigue and reduced sleep quality.

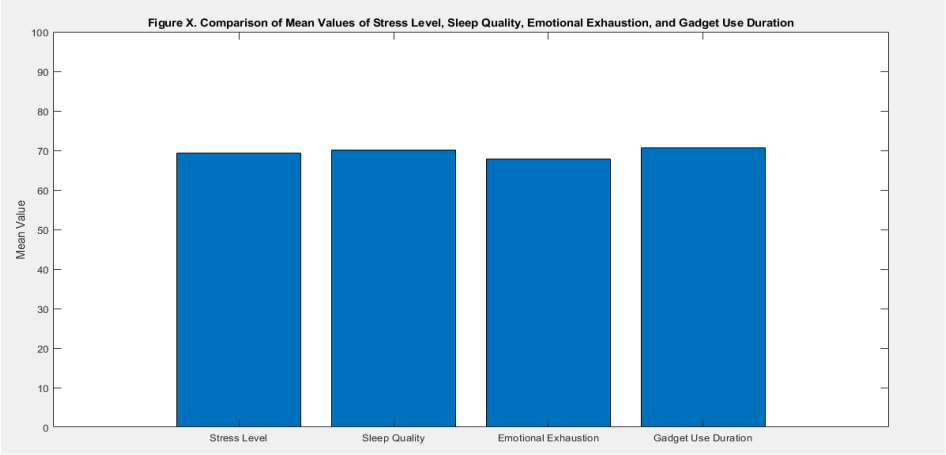

Figure 6. Comparison of Mean Values of Stress Level, Sleep Quality, Emotional Exhaustion, and Gadget Use Duration

Figure 6. Presents a comparison of the mean values of stress level, sleep quality, emotional exhaustion, and gadget use duration among final-year students. The results show that all variables have relatively high mean values, ranging from 67 to 71. Gadget use duration has the highest mean value (70.6), indicating a high intensity of gadget usage among students. Sleep quality and stress level also show high mean values of 70.1 and 69.4, respectively, reflecting considerable academic pressure that affects students' rest patterns. Emotional exhaustion has the lowest mean value (67.8), yet it remains in the moderate-to-high category. Overall, the graphic indicates that these four variables contribute significantly and relatively equally to the assessment of students' mental health levels and are therefore appropriate as input variables in the Tsukamoto fuzzy logic model.

III. METODE

A. Rule Base and Inference

Fuzzy rules and Inference are constructed using 81 fuzzy rules used to relate input and output variables. The second stage of forming a rule base (81 IF–THEN rules), Stage of Tsukamoto inference by calculating the a-predicate value (fire strength) for each rule using the MIN (AND) operator.The following are the fuzzy logic rules:

Table 4. *Rules Base*

No	Variable				
	Input				Output
	Stress Level	Sleep Quality	Emotional Exhaustion	Gadget Use Duration	Mental Health
R1	Low	Bad	Low	Low	Good
R2	Low	Bad	Low	Medium	Medium
R3	Low	Bad	Low	High	Medium
R4	Low	Bad	Medium	Low	Good
R5	Low	Bad	Medium	Medium	Medium
R6	Low	Bad	Medium	High	Medium
R7	Low	Bad	High	Low	Medium
R8	Low	Bad	High	Medium	Medium
R9	Low	Bad	High	High	Bad
R10	Low	Enough	Low	Low	Good
R11	Low	Enough	Low	Medium	Good
R12	Low	Enough	Low	High	Medium
R13	Low	Enough	Medium	Low	Good
R14	Low	Enough	Medium	Medium	Medium
R15	Low	Enough	Medium	High	Medium
R16	Low	Enough	High	Low	Medium
R17	Low	Enough	High	Medium	Medium
R18	Low	Enough	High	High	Medium
R19	Low	Good	Low	Low	Good
R20	Low	Good	Low	Medium	Good
R21	Low	Good	Low	High	Good
R22	Low	Good	Medium	Low	Good
R23	Low	Good	Medium	Medium	Good
R24	Low	Good	Medium	High	Medium
R25	Low	Good	High	Low	Good
R26	Low	Good	High	Medium	Medium
R27	Low	Good	High	High	Medium
R28	Medium	Bad	Low	Low	Medium

R29	Medium	Bad	Low	Medium	Medium
R30	Medium	Bad	Low	High	Medium
R31	Medium	Bad	Medium	Low	Medium
R32	Medium	Bad	Medium	Medium	Medium
R33	Medium	Bad	Medium	High	Bad
R34	Medium	Bad	High	Low	Medium
R35	Medium	Bad	High	Medium	Bad
R36	Medium	Bad	High	High	Bad
R37	Medium	Enough	Low	Low	Good
R38	Medium	Enough	Low	Medium	Medium
R39	Medium	Enough	Low	High	Medium
R40	Medium	Enough	Medium	Low	Medium
R41	Medium	Enough	Medium	Medium	Medium
R42	Medium	Enough	Medium	High	Medium
R43	Medium	Enough	High	Low	Medium
R44	Medium	Enough	High	Medium	Medium
R45	Medium	Enough	High	High	Bad
R46	Medium	Good	Low	Low	Good
R47	Medium	Good	Low	Medium	Good
R48	Medium	Good	Low	High	Medium
R49	Medium	Good	Medium	Low	Good
R50	Medium	Good	Medium	Medium	Medium
R51	Medium	Good	Medium	High	Medium
R52	Medium	Good	High	Low	Medium
R53	Medium	Good	High	Medium	Medium
R54	Medium	Good	High	High	Medium
R55	High	Bad	Low	Low	Medium
R56	High	Bad	Low	Medium	Medium
R57	High	Bad	Low	High	Bad
R58	High	Bad	Medium	Low	Medium
R59	High	Bad	Medium	Medium	Bad
R60	High	Bad	Medium	High	Bad
R61	High	Bad	High	Low	Bad
R62	High	Bad	High	Medium	Bad
R63	High	Bad	High	High	Bad
R64	High	Enough	Low	Low	Medium
R65	High	Enough	Low	Medium	Medium
R66	High	Enough	Low	High	Medium
R67	High	Enough	Medium	Low	Medium
R68	High	Enough	Medium	Medium	Medium
R69	High	Enough	Medium	High	Bad
R70	High	Enough	High	Low	Medium
R71	High	Enough	High	Medium	Bad
R72	High	Enough	High	High	Bad
R73	High	Good	Low	Low	Good
R74	High	Good	Low	Medium	Medium
R75	High	Good	Low	High	Medium
R76	High	Good	Medium	Low	Medium
R77	High	Good	Medium	Medium	Medium

R78	High	Good	Medium	High	Medium
R79	High	Good	High	Low	Medium
R80	High	Good	High	Medium	Medium
R81	High	Good	High	High	Bad

B. Defuzzification

Stage of defuzzification produces the final crisp value through a weighted average using the Weighted Average (WA) method.

With the formula:

$$Z = \frac{\sum ai \; x \; zi}{\sum ai}$$

Description:

αi = degree of truth (fire strength) of the i-th rule → the result of the MIN operation on the input pooling function.

Zi = crisp value of the output pooling function based on αi

Z = final defuzzification result (clear value of mental health level)[18].

D. Accuracy Evaluation

Model Accuracy Evaluation The model is tested by comparing the predicted results with the actual data, calculated using the Mean Absolute Percentage Error (MAPE):

$$MAPE \; \frac{A-P}{A} \text{ x } 100\%$$

Where:

A = Actual Value (Expert).

P = Predicted Value (Tsukamoto defuzzification result)[19]

III. RESULT AND DISCUSSION

The Tsukamoto fuzzy logic model was successfully implemented on the MATLAB GUI platform[20]. The system provides an interface for inputting information on stress, sleep quality, emotional exhaustion, and device usage duration. The system then generates a mental health score in clear output and linguistic categories (good, medium, bad). Table 5 presents a summary of the model accuracy evaluation based on all respondents.

Table 5. Summary of Model Accuracy Evaluation

Indicator	Value
Indicator Value Number of Respondents	50
Average MAPE (%)	19.34
Accuracy Category	Good

The accuracy evaluation results indicate that the Tsukamoto fuzzy logic model achieves an average MAPE value of 19.34%, which falls within the “good” accuracy category. This result suggests that the proposed model is capable of producing predictions that are reasonably consistent with expert assessments. The use of fuzzy logic effectively handles uncertainty in mental health assessment, allowing complex psychological conditions to be represented through linguistic variables and crisp output values.

To determine the level of model accuracy, the following MAPE category ranges are used:

Table 6. MAPE Range

MAPE Value Range (%)	Accuracy Category	Interpretation
< 10%	Very Good	The model is very accurate in predicting
10% – 20%	Good	The model is fairly accurate
20% – 50%	Medium	The model has a moderate error rate
> 50%	Bad	The model is less accurate

V. CONCLUSION

This study shows that the Tsukamoto fuzzy method can be used effectively to determine the mental health level of final semester students. Based on the results of the number of data, the MAPE value using MATLAB is 19.34%. So the model is categorized as good so that the model is quite accurate to the mental health condition of final semester students. Based on the MAPE category, the value is in the range of 10%–20%, included in the good accuracy category. This shows that the developed Tsukamoto fuzzy model is able to provide predictive results that are quite in accordance with actual data, so it can be used as a decision support system model in assessing the mental health condition of students more objectively and measurably.

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