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IMPLEMENTATION OF THE FUZZY TSUKAMOTO METHOD TO EARLY DETECTION TYPES OF GASTRIC DISEASES

Rizka Nur Kholifah[1], Nuril Lutvi Azizah[*,2]
[1,2] Informatics Study Program, Muhammadiyah Universitas of Sidoarjo, Indonesia

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ABSTRACT

Abstract: The stomach is a critical organ within the human digestive system, and gastric diseases represent significant health concerns often underestimated by the public. Factors such as poor dietary habits, stress, and bacterial infections contribute to these ailments, whose initial symptoms can easily be misinterpreted due to their similarity with other gastrointestinal disorders. **The knowledge** gap exists in the diagnostic challenges faced by both patients and healthcare professionals, necessitating the development of improved diagnostic tools. **This study aims** to enhance the diagnostic process for gastric diseases through the implementation of an expert system utilizing the Fuzzy Tsukamoto method. By employing questionnaires and expert interviews to gather data on symptoms, we develop a comprehensive fuzzy inference system. **Results** indicate that the system accurately classifies stomach ailments based on user-reported symptoms, facilitating early diagnosis and treatment. The **novelty** of this research lies in the application of the Fuzzy Tsukamoto method, which allows for nuanced symptom analysis and inference, providing a more accessible means for the general public to identify potential gastric diseases. Furthermore, the system design includes flowcharts, data flow diagrams, and entity relationship diagrams to ensure a user-friendly interface. **The implications** of this study are significant, as it offers a robust tool for early detection of gastric diseases, thereby potentially improving patient outcomes and reducing healthcare costs associated with late-stage interventions. This expert system not only assists in diagnosing gastric conditions but also serves as a valuable resource for enhancing the understanding of symptomology in gastroenterology.

Corresponding Author:
Nuril Lutvi Azizah
Informatics Study Program, Muhammadiyah Universitas of Sidoarjo
E-mail : nurillutviazizah@umsida.ac.id
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INTRODUCTION

The stomach is one of the important organs for humans because it is one of the digestive organs to digest food and drinks consumed by humans [1]. Gastric disease is one of the diseases that should not be taken lightly or underestimated. Why is that?

Because if you leave gastric diseases untreated, it can cause complications or the appearance of other diseases. If not handled correctly, it can cause death. Gastric disease can also be caused by stress, irregular diet, as well as infectious bacteria [2]. In carrying out treatment such as gastric diseases, people in general prefer to do treatment independently by looking at the symptoms that appear because they are considered more economical and energy-saving [3].

Disease symptoms are the initial conditions when illness comes. From the initial symptoms felt, patients with the disease can make predictions to find out what disease they are suffering. From the development of technology in the field of medicine today, an expert system can be applied to determine the risks arising from the symptoms felt [4]. Expert systems are computer programs that can resemble the abilities of an expert. It can be interpreted that this computer program can resemble the ability of humans who have special skills [5]. Based on the problems that have been presented above, the author conducted a research entitled "Implementation of the Fuzzy Tsukamoto Method for Early Detection of Gastric Diseases". This expert system was built with the aim of being able to detect gastric diseases early, namely ulcers, dyspepsia, GERD and gastritis by including the symptoms experienced by the sufferer.

It is hoped that this research can help and make it easier for the community to know the diseases in the stomach early and can immediately handle them to prevent the emergence of other diseases caused by gastric diseases.

METHODS

In this chapter, we use a data collection method, namely in the form of filling out questionnaires for data collection specifically for the age of 17 years and above and also conducting an interview data collection method or interview that functions to obtain data on disease symptoms in the stomach from experts. After the data is collected, the next stage, namely raw data, is processed using the fuzzy tsukamoto method and making a system design.

A. **Fuzzy Method**

Fuzzy Tsukamoto means one type of inference system that has the same membership function [6]. Tsukamoto's fuzzy method is more intuitive, and can be accepted by many parties. So it is more suitable for input received from humans rather than machines [7]. There are several stages in the Fuzzy Tsukamoto method, namely

a. **Fuzzification**

This stage is the stage of forming a fuzzy set consisting of variables *Input* and also variables *Output* [8]. The variable is divided into one or more fuzzy sets. Here is a table of fuzzy sets:

Table 1. Fuzzy Bundle [9]

Variable		Fuzzy Bundle		Domain	Function Membership	Parameter
Name	Symbol	Name	Symbol			
Symptoms of Ulcers	M	Low	R	[1,6]	Linear turun	[1,9]
		Tall	T	[7,9]	Linear naik	[1,9]
Symptom Gastritis	A	Low	R	[1,4]	Linear turun	[1,9]
		Tall	T	[5,9]	Linear naik	[1,9]
Symptom Dyspepsia	D	Low	R	[1,6]	Linear turun	[1,10]
		Tall	T	[7,10]	Linear naik	[1,10]
Symptoms of GERD	And	Low	T	[1,3]	Linear naik	[1,8]
		Tall	T	[4,8]	Linear turun	[1,8]

Function of the degree of membership of the variable of ulcer symptoms.

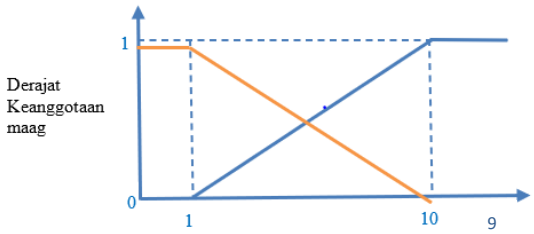

Figure 1. Membership of Ulcer Symptom Variables [10]

$$\mu R\,(m) = \begin{cases} 1 & ;\ x \le 1 \\ \frac{9-x}{9-1} & ;1 \le x \le 9 \\ 0 & ;x \ge 9 \end{cases}$$

Linear representation down

$$\mu T\,(m) = \begin{cases} 0 & ;\ x \le 1 \\ \frac{x-9}{9-1} & ;1 \le x \le 9 \\ 1 & ;x \ge 9 \end{cases}$$

Linear representation up

b. **Formation of Rules**

The formation of IF-THEN Rules is the process of forming Rules that will be used in the form of IF-THEN stored in the fuzzy membership base [10]. In the fuzzy set there are several representations of membership functions, one of which is the representation of the lineear. So that the following rules can be formed:

[R1] IF Indikator 1 AND Indikator 2 AND Indikator n THEN Maag

[R2] IF Indikator 1 AND Indikator 2 AND Indikator n THEN Gastritis

[R3] IF Indikator 1 AND Indikator 2 AND Indikator n THEN Dispepsia

[R4] IF Indikator 1 AND Indikator 2 AND Indikator n THEN GERD

Table 2. Formation of Rules [11]

No	IF	INDICATOR	SO	DISEASE
1.	***IF***	Feeling nauseous after eating, feeling nauseous to vomiting after eating, feeling full quickly after eating, feeling full for a long time after eating, feeling bloated after eating, burping frequently, also frequent gassing (farting), having felt sour in the mouth, feeling stomach acid rising into the esophagus, often experiencing diarrhea in the last few weeks. [12]	***THEN***	Stomach
2.	***IF***	Feeling nauseous after eating, feeling nauseous to vomiting after eating, feeling full quickly after eating, bloating after eating, frequent hiccups, feeling hot (like burning) in the heartburn, experiencing pain in the heartburn, your weight loss, having a bowel movement with black stools or stools. [13]	***THEN***	Gastritis
3.	***IF***	Feeling nauseous after eating, feeling nauseous to vomiting after eating, feeling full quickly after eating, bloating regularly, burping frequently, feeling difficulty swallowing food, feeling heat in the chest area, feeling sore in the upper abdomen,	***THEN***	Dyspepsia

		experiencing pain in the heartburn, your weight has decreased. [14]		
4.	***IF***	Feeling nauseous after eating, feeling nauseous to vomiting after eating, your mouth smells bad, experiencing hoarseness, difficulty swallowing food due to discomfort in the throat, pain in the throat, respiratory disorders such as coughing and shortness of breath, experiencing sleep disturbances. [12]	**THEN**	GERD

B. **System Planning**

After the stage of the fuzzy method, namely the system design stage consisting of flowchart, DFD, ERD, and the last is the Usecase Diagram.

a. **Flowchart**

The first stage is the design of the flowchart which is the stages of system design starting from the dashboard, then logging in if you already have an account. If you don't have an account, you must first create an account by filling in the data as soon as what data is needed by the system. After having an account and successfully logging in, the next step is to enter the consultation menu and fill in the symptoms that have been experienced. After filling out the consultation form, you can click calculate to find out the results of the consultation. The following is a flowchart image for system design:

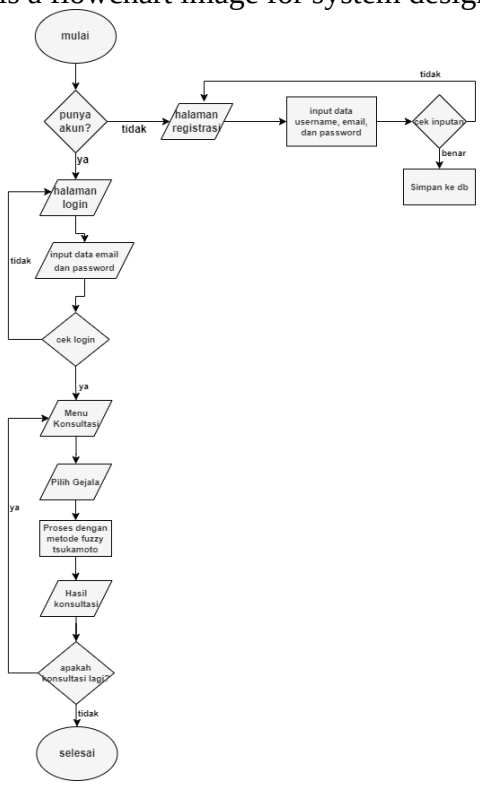

Figure 2. Flowchart

b. **DFD**

After creating a flowchart, the next stage is *context diagram* or a context diagram used to illustrate interactions between users or *user* and the system itself [14]. Admins can enter symptom data, disease data, solution data, and rule data. Admins can also find out registration data and consultation results from users. For users, they can enter registration data, consultation data, and can find out information from the results of the consultation. Here is a DFD image or context diagram for system planning:

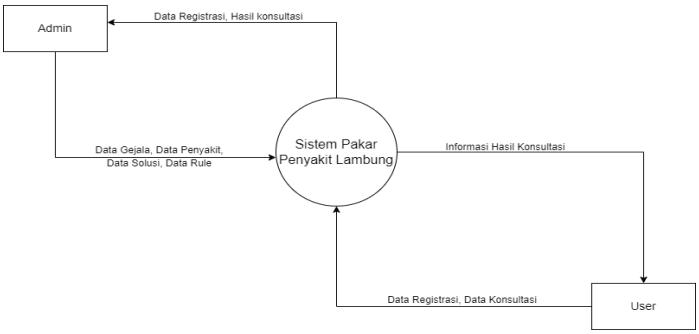

Figure 3. Context Diagram

c. **ERD**

The next stage after DFD is ERD or *Entity Relationship Diagram* that is a description of the relationships between data in a database based on data objects that model the data structure and relationships between data, and use several symbols to describe them [6]. It can be seen that the ERD for system design in the figure below in the system design has six entities, namely users, consultations, rules, solutions, diseases, and symptoms, each of which has its own attributes:

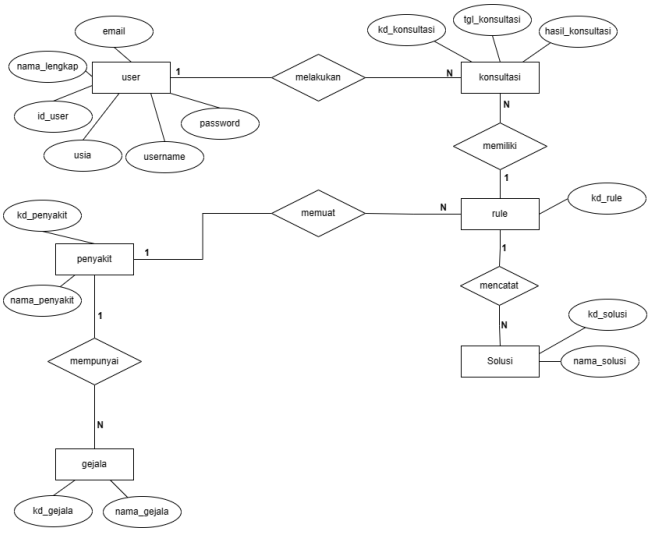

Figure 4. ERD

d. **Usecase Diagram**

The last stage in the design of this system is a usecase diagram used to illustrate the relationship between the user and the system. Below is an image of the Usecase Diagram for system planning that explains that admins can change login data, dashboards, consultation registrations, registration data and users can see logins, dashboards, symptom consultations, and also consultation results:

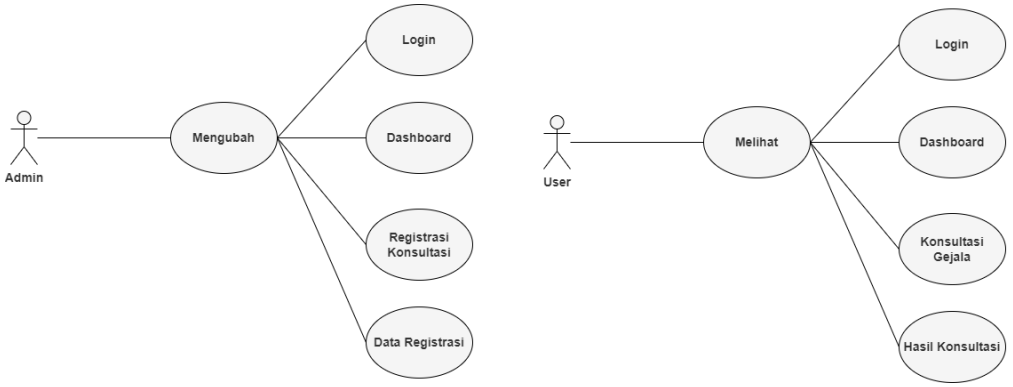

Figure 5. Usecase Diagram

RESULT AND DISSCUSION

After going through the stages of data collection, fuzzy logic methods, and system design stages. So the next is to discuss the results obtained from the stages that have been discussed previously.

A. Data Collection

The first stage is the stage of data collection with interview methods and questionnaires. At the stage of data collection with interview techniques, which produce data on symptoms of gastric diseases and the stage of filling out questionnaires produces data on respondents who experience symptoms of gastric disease.

a. Interview Data Collection

At the stage of collecting data interviews, interviews with experts (Dr. Dewi Rahayu S.) aim to obtain data from valid symptoms of gastric diseases and also from several references from journals to add some symptoms of gastric diseases for questioning. After going through a question and answer with an expert (Dr. Dewi Rahayu S.) so that the results of the data on the symptoms of diseases in the stomach were obtained as follows:

Table 3. Symptoms of the disease [1]

DISEASE	SYMPTOMS OF GASTRIC DISEASE
Stomach	1. Feeling nauseous after eating 2. Feeling nauseous to vomiting after eating 3. Feeling full quickly after eating 4. Feeling full for a long time after eating 5. Feeling bloated after eating 6. Frequent burping, also frequent gassing (farting) 7. Have ever felt a sour taste in the mouth 8. Feeling stomach acid rise into the esophagus 9. Frequent diarrhea in recent weeks
Gastritis	1. Feeling nauseous after eating 2. Feeling nauseous to vomiting after eating 3. Feeling full quickly after eating 4. Flatulence after eating 5. Frequent hiccups 6. Feeling heat (like burning) in the heartburn 7. Experiencing pain in heartburn 8. Your weight has decreased 9. Bowel movements with black stools or stools
Dyspepsia	1. Feeling nauseous after eating 2. Feeling nauseous to vomiting after eating 3. Feeling full quickly after eating 4. Flatulence routinely 5. Frequent burping 6. Feeling difficulty swallowing food 7. Feeling a feeling of heat in the chest area 8. Feeling pain in the upper part of the abdomen 9. Experiencing pain in heartburn 10. Your weight has decreased
GERD	1. Feeling nauseous after eating 2. Feeling nauseous to vomiting after eating 3. Your mouth smells bad 4. Experiencing hoarseness 5. Difficulty swallowing food due to discomfort in the throat

6. Sore throat
7. Respiratory disorders such as coughing and shortness of breath
8. Have sleep disturbances

After getting data on the symptoms of gastric disease. So the data is made into one as shown in table 4 as data *input* for calculations in the fuzzy method and system design. The following are the symptoms of all gastric diseases from the results of the stages of collecting interview data or interviews and also from the reference of journals that have been converted into disease symptom codes with a total of twenty-four symptoms:

Table 4. Disease Symptom Codes

SYMPTOM CODES	SYMPTOMS OF GASTRIC DISEASE
GP01	Feeling nauseous after eating
GP02	Feeling nauseous to vomiting after eating
GP03	Feeling full quickly after eating
GP04	Feeling full for a long time after eating
GP05	Feeling bloated after eating
GP06	Hiccups
GP07	Frequent burping
GP08	Frequent burping and also frequent gassing (farting)
GP09	Feeling sour taste in the mouth
GP10	Bad breath smell
GP11	Experiencing bloating regularly
GP12	Feeling stomach acid rise into the esophagus
GP13	Having a sore throat
GP14	difficulty swallowing food due to discomfort in the throat
GP15	Experiencing hoarseness
GP16	Feeling heat (like burning) in the heartburn

GP17	feeling the heat in the chest area
GP18	Feeling pain in the upper part of the abdomen
GP19	experiencing pain in heartburn
GP20	Experiencing breathing disorders such as coughing and shortness of breath
GP21	Have a sleep disorder related to these symptoms
GP22	Having diarrhea in recent weeks
GP23	Weight loss is significant
GP24	Bowel movements with black stools or stools

b. Questionnaire Data Collection

After the data on the symptoms of the disease has been collected, the data is processed into questionnaire questions and then distributed to respondents who experience symptoms of gastric disease. For data collection through questionnaires, data was collected from 20 respondents who had stomach problems or pain. The following is the data from filling out the questionnaire:

Table 5. Questionnaire Filling Results

Respond	Age	Gender	There are complaints	Symptoms of gastric disease
R01	24	Woman	Yes	GP01, GP05, GP11, GP12, GP16, GP17, GP18, GP19, GP22
R02	17	Man	Yes	GP03, GP04, GP05, GP09, GP11, GP12, GP16, GP17, GP18, GP19, GP21
R03	22	Woman	Yes	GP02, GP09, GP12, GP15, GP18, GP19, GP20, GP21
R04	20	Man	Yes	GP01, GP02, GP05, GP07, GP09, GP12, GP15, PG17, GP21, GP23, GP24
R05	26	Woman	Yes	GP03, GP05, GP06, GP08, GP09, GP12, GP13, GP14, GP16, GP18, GP21, GP23, GP24
R06	23	Woman	Yes	GP01, GP02, GP05, GP06, GP07, GP09, GP12, GP16, GP18, GP20, GP21
R07	20	Woman	Yes	GP01, GP03, GP05, GP09, GP10, GP12, GP16, GP17, GP18, GP19, GP21, GP22
R08	24	Woman	Yes	GP01, GP02, GP03, GP06, GP07, GP08, GP09, GP10, GP15, GP21, GP24
R09	23	Woman	Yes	GP01, GP03, GP04, GP06, GP07, GP13, GP14, GP15, GP20, GP21, GP24
R10	23	Woman	Yes	GP01, GP02, GP03, GP04, GP06, GP09, GP12, GP14, GP16, GP17, GP18, GP19, GP21, GP23

R11	17	Woman	Yes	GP01, GP02, GP03, GP04, GP07, GP08, GP09, GP10, GP12, GP14, GP16, GP18, GP19, GP21
R12	23	Woman	Yes	GP02, GP05, GP07, GP10, GP12, GP14, GP20, GP22
R13	28	Woman	Yes	GP01, GP02, GP03, GP04, GP05, GP06, GP07, GP09, GP11, GP12, GP15, GP16, GP17, GP18, GP19, GP20, GP21, GP22, GP23, GP24
R14	23	Woman	Yes	GP01, GP02, GP05, GP07, GP08, GP10, GP11, GP12, GP13, GP14, GP16, GP17, GP18, GP19, GP20, GP21, GP24
R15	19	Woman	Yes	GP01, GP02, GP03, GP11, GP16, GP18, GP23
R16	29	Man	Yes	GP01, GP03, GP04, GP05, GP07, GP08, GP12, GP15, GP17, GP18, GP19, GP20
R17	23	Man	Yes	GP01, GP04, GP05, GP07, GP08, GP10, GP15, GP17, GP20, GP22, GP24
R18	23	Man	Yes	GP02, GP03, GP09, GP12, GP15, GP17, GP18, GP21
R19	22	Woman	Yes	GP01, GP03, GP07, GP09, GP15, GP18, GP20
R20	23	Woman	Yes	GP02, GP03, GP05, GP06, GP07, GP08, GP09, GP11, GP12, GP18, GP20

B. Tsukamoto's Fuzzy Method

This method discusses the stages of calculating the fuzzy tsukamoto method which consists of fuzzication and rules.

a. Fuzzification

The first step that must be done is to find the membership of each input variable [15].

1. Stomach

$$\mu R\,(m) = \begin{cases} 1 & ;\ x \le 1 \\ \frac{6-x}{6-1} & ;1 \le x \le 6 \\ 0 & ;x \ge 6 \end{cases} \qquad \mu T\,(m) = \begin{cases} 0 & ;\ x \le 7 \\ \frac{x-9}{9-1} & ;7 \le x \le 9 \\ 1 & ;x \ge 9 \end{cases}$$

Low fuzzy set High fuzzy set

2. Gastritis

$$\mu R\,(a) = \begin{cases} 1 & ;\ x \le 1 \\ \frac{4-x}{4-1} & ;1 \le x \le 4 \\ 0 & ;x \ge 4 \end{cases} \qquad \mu T\,(a) = \begin{cases} 0 & ;\ x \le 5 \\ \frac{x-10}{10-1} & ;5 \le x \le 10 \\ 1 & ;x \ge 10 \end{cases}$$

Low fuzzy set High fuzzy set

3. Dyspepsia

$$\mu R\,(d) = \begin{cases} 1 & ;\ x \le 1 \\ \frac{6-x}{6-1} & ;1 \le x \le 6 \\ 0 & ;x \ge 6 \end{cases} \qquad \mu T\,(d) =$$

$$\begin{cases} 0 & ;\ x \le 7 \\ \frac{x-9}{9-1} & ;7 \le x \le 9 \\ 1 & ;x \ge 9 \end{cases}$$

Low fuzzy set High fuzzy set

4. GERD

$$\mu R\,(and) = \begin{cases} 1 & ;\ x \le 1 \\ \frac{3-x}{3-1} & ;1 \le x \le 3 \\ 0 & ;x \ge 3 \end{cases} \qquad \mu T\,(and) =$$

$$\begin{cases} 0 & ;\ x \le 1 \\ \frac{x-8}{8-1} & ;1 \le x \le 8 \\ 1 & ;x \ge 8 \end{cases}$$

Low fuzzy set High fuzzy set

b. Rule

To detect whether the user suffers from a stomach disease or not, rules are formed like this:

Rules for ulcers

Table 6. Rule Maag [16]

Function	Variable	Domain	Fuzzy Bundle
Input	Feeling nauseous after eating	1-6	Low
	Feeling nauseous to vomiting after eating	1-6	Low
	Feeling full quickly after eating	1-6	Low
	Feeling full for a long time after eating	1-6	Low
	Feeling bloated after eating	1-6	Low
	Frequent burping, also frequent gassing (farting)	1-6	Low
	Have ever felt a sour taste in the mouth	7-9	Tall
	Feeling stomach acid rise into the esophagus	7-9	Tall
	Frequent diarrhea in recent weeks	7-9	Tall
Output	Stomach	1-9	

[1] IF feels nauseous after a low meal AND feels full quickly after a low meal THEN ulcer
[2] IF has felt a sour taste in the mouth is high AND often has diarrhea in recent weeks THEN high ulcer

C. System Testing

From the data obtained in the data collection stage, the data can be entered into the database to be *input* into the system. From the design of the system as described earlier, so that it can produce a system. UI (*User Interface*) is the visual part of a website, application, software, or hardware that determines how users interact with a product. This system is divided into two, namely for users and admins. In the image below, there is adashboard display for users and admins, then users and admins enter the sign up menu to create an account first.

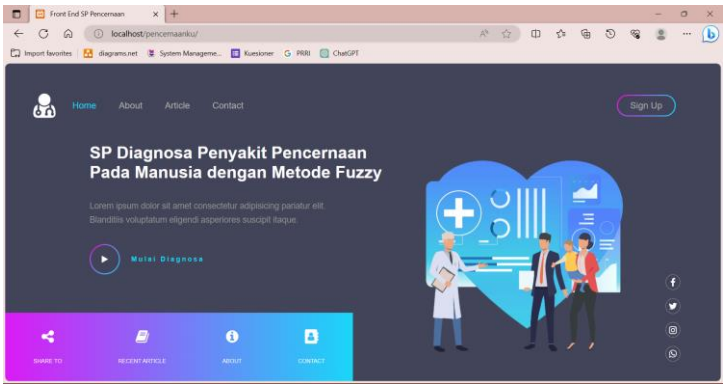

Figure 6. Dashboard

If the user or admin does not have an account, the first step is to create an account first by filling in the data that has been listed in the sign up column so that they can enter the system.

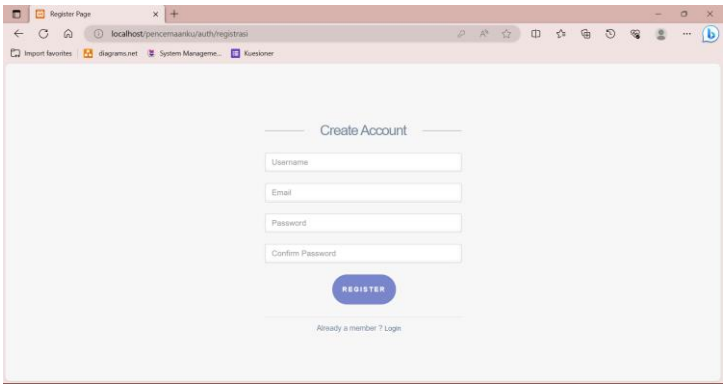

Figure 7. Sign Up

If the user or admin already has an account, then the user or admin can fill in the email and password to log in to the system.

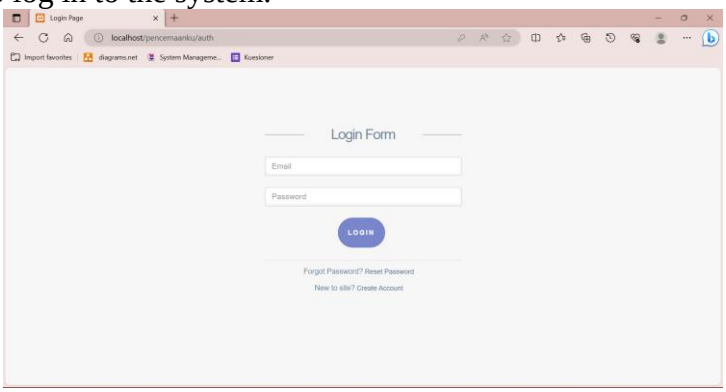

Figure 8. Login Menu

After the admin logs in, the main page that appears is like this. There is a difference between the user dashboard and the admin dashboard page. In the admin dashboard there is a menu of rules, symptoms, diseases, diagnosis results, and the last is an article.

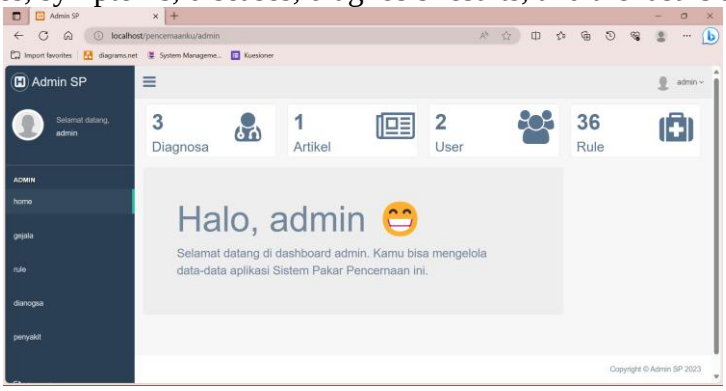

Figure 9. Admin Dashboard

The symptom menu displays symptoms and symptom codes. In this menu you can also add symptoms, change symptoms, and also remove symptoms.

Figure 10. Menu Symptoms

Next is the stomach diseases page which functions to fill, edit, and delete the rules of each disease symptom.

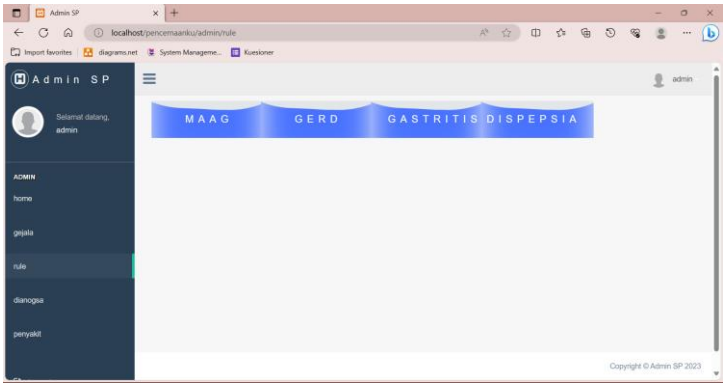

Figure 11. Stomach Diseases Page

This is an overview of one of the pages of the ulcer rule. On this page, admins can add, change, and also delete rules for ulcers.

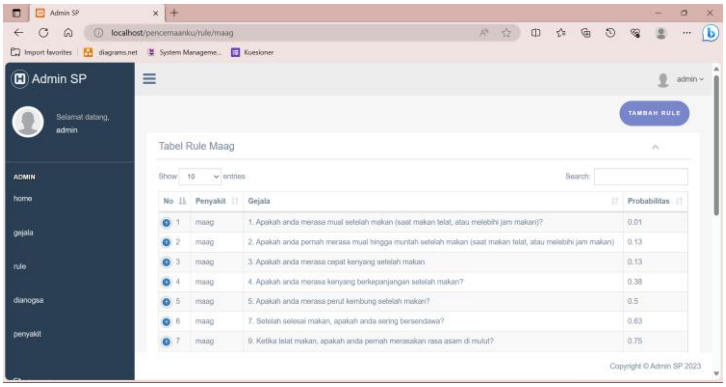

Figure 12. Ulcer Rule Page

On this page, admins can add diseases, edit disease codes, disease names, probabilities, suggestions for diseases, and also disease information, the last of which is that admins can delete disease data.

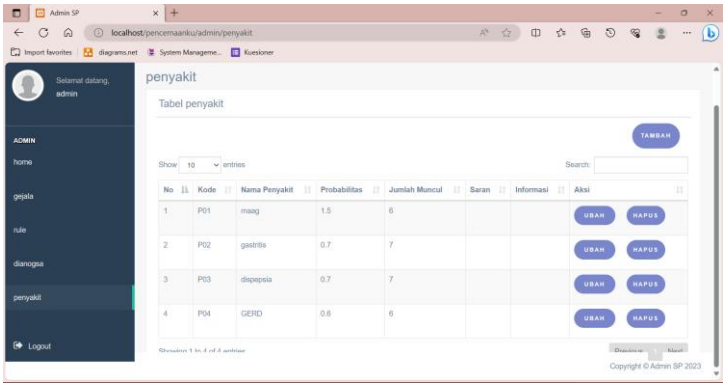

Figure 13. Disease Table Page

Admins can find out the results of consultations conducted by users on this page.

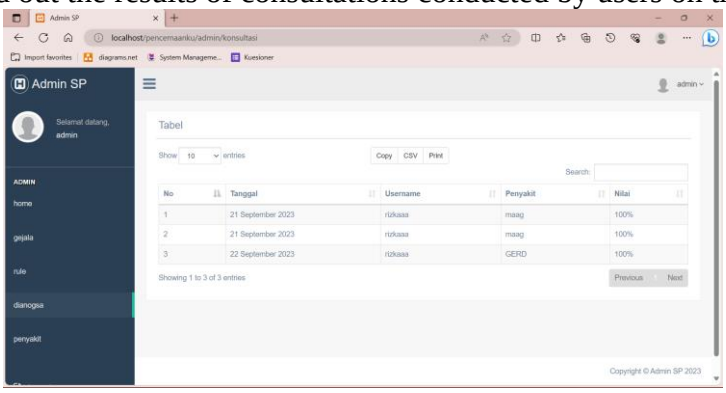

Figure 14. Diagnostic Results Page

For *users*, the home page is the dashboard

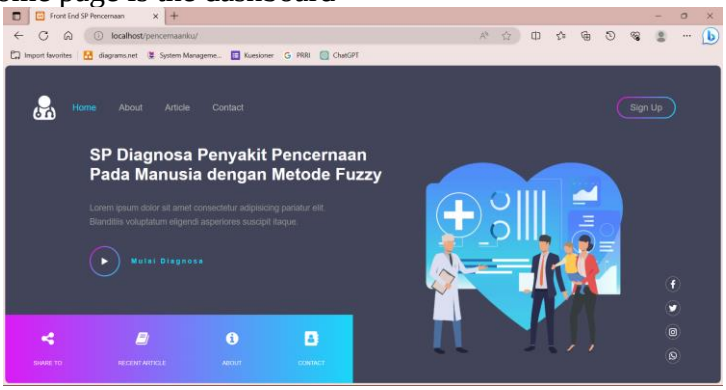

Figure 15. Dashboard

After successfully logging in, the user first enters the dashboard page. Furthermore, users can consult symptoms on this page by filling in at least seven symptom complaints that users experience. Why do you have to fill in at least seven symptoms? Because the symptoms of gastric disease look similar and if you fill in less than seven, the results are less accurate because some of the symptoms are similar. In order for the results of the consultation to come out more accurately, the user must fill in at least seven symptoms of what disease is being experienced by the user so that the system can identify what disease the user is suffering from.

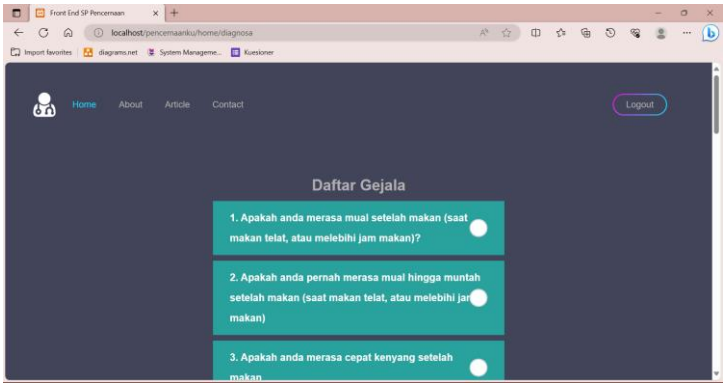

Figure 16. Consultation Page

After filling in, the user will find out the results of filling out the previous symptom form. This page displays the results of predicting what diseases the user suffers from and also the percentage of how much the user has the disease.

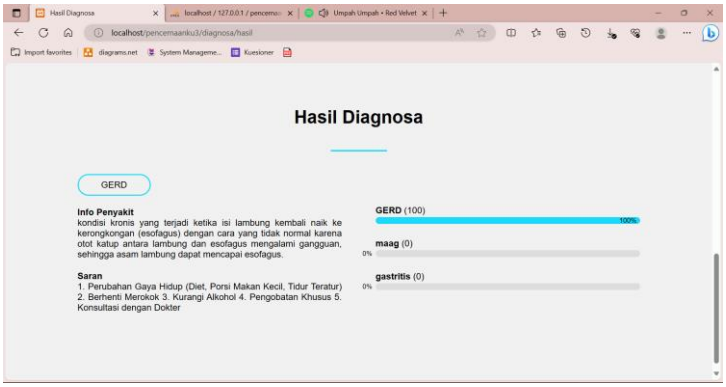

Figure 17. Consultation Results Page

In the diagnosis results, it displays the disease with the highest results in the calculation of the weight of the disease symptoms that have been filled in by the user. For example, in figure 17 which shows that the user suffers from GERD disease. After conducting the system test, then get the results of the system test as shown in the table below:

Table 7. System Test Results

Respond	Age	Gender	There are complaints	Diseases suffered
R01	24	Woman	Yes	GERD
R02	17	Man	Yes	GERD
R03	22	Woman	Yes	Stomach
R04	20	Man	Yes	Stomach
R05	26	Woman	Yes	GERD
R06	23	Woman	Yes	Stomach
R07	20	Woman	Yes	GERD
R08	24	Woman	Yes	Dyspepsia
R09	23	Woman	Yes	Dyspepsia
R10	23	Woman	Yes	GERD
R11	17	Woman	Yes	GERD
R12	23	Woman	Yes	Dyspepsia
R13	28	Woman	Yes	GERD
R14	23	Woman	Yes	Stomach
R15	19	Woman	Yes	GERD
R16	29	Man	Yes	GERD
R17	23	Man	Yes	GERD
R18	23	Man	Yes	GERD
R19	22	Woman	Yes	GERD
R20	23	Woman	Yes	GERD

Based on the results of the system test, it was shown that there were 13 respondents who suffered from GERD, 4 respondents who suffered from ulcers, 3 respondents who suffered from Dyspepsia, and 0 respondents who suffered from Gastritis.

CONCLUSION

Conclusion: This study demonstrates that the Fuzzy Tsukamoto method can effectively be utilized for the early diagnosis of gastric diseases by quantifying the significance of various symptoms reported by users. The **fundamental finding** is that the expert system not only improves diagnostic accuracy but also enhances patient engagement in the healthcare process, allowing individuals to better understand their symptoms and seek timely medical attention. The **implications** of this research are substantial, as this system has the potential to reduce the incidence of misdiagnosis and late-stage treatment, ultimately leading to better patient outcomes and more efficient use of healthcare resources. However, **the limitations** of this study include the reliance on self-reported symptoms, which may vary in accuracy, and the necessity for further validation through clinical trials to ensure the system's reliability across diverse populations. **Future research** should focus on expanding the dataset, integrating machine learning techniques to refine diagnostic capabilities, and exploring user experience to enhance the interface and accessibility of the system for broader public use.

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