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Expert System for GERD Diagnosis Based on Fuzzy Logic at dr. Rumbang Sembiring, Sp.PD's Practice

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Abstract

Gastroesophageal Reflux Disease (GERD) is a chronic digestive disorder characterized by chest burning (heartburn), epigastric pain, nausea, regurgitation of stomach contents, difficulty swallowing, sleep disturbances, and chronic cough. Conventional diagnostic methods like medical interviews and endoscopy have limitations in terms of time, cost, and access. This research aims to design and implement an Expert System for GERD Diagnosis based on Mamdani Fuzzy Logic with the Forward Chaining method to assist in rapid, accurate, and efficient initial diagnosis. Primary data was collected from the practice of dr. Rumbang Sembiring, Sp.PD (Internist), in the form of intensity values for seven main GERD symptoms. The system was developed as a web-based application using Python and PHP programming languages, involving the stages of fuzzification, inference based on IF-THEN rules using forward chaining, aggregation, and defuzzification using the centroid method to produce a category of GERD likelihood (low, medium, high). Evaluation was conducted by comparing the system's results with the doctor's diagnosis on 40 test data points. The test results showed an accuracy rate of 87.5%, indicating that the system can represent expert knowledge very well. This system is expected to be an initial diagnostic aid for medical personnel and patients and can be further developed by adding symptom variables and mobile application integration..

Kata Kunci: Diagnosis; Fuzzification; Forward Chaining; GERD; Expert System

1. INTRODUCTION

Gastroesophageal Reflux Disease (GERD) is one of the most common chronic digestive disorders encountered in society. This disease is characterized by the reflux of stomach acid into the esophagus, causing various symptoms, including epigastric pain, chest burning sensation (heartburn), nausea, regurgitation, sleep disturbances, and even chronic cough. If not treated properly, this condition can potentially reduce the patient's quality of life and develop into serious complications such as esophagitis, esophageal stricture, and even esophageal cancer. The high incidence of GERD, which often goes undiagnosed in the early stages, makes it an important issue in healthcare services. This is also evident in the medical practice at the clinic of dr. Rumbang Sembiring, Sp.PD, where many patients present with varied and non-specific complaints. Various studies show a relationship between lifestyle and the onset of GERD symptoms. Didik Kuswono et al. (2021) reported that individuals with poor dietary patterns have a higher prevalence of GERD compared to those with healthy diets. Another study by Bunga et al. (2020) found that approximately 34.2% of respondents with unhealthy eating patterns experienced GERD, while 86.5% of the group with healthy eating patterns did not experience the disease. Meanwhile, a study by Putri Saraswati et al. (2021) on 86 respondents showed that coffee consumption habits also have an influence, where 14% of respondents were diagnosed with GERD, while the rest showed no symptoms of the disease. These findings reinforce that lifestyle factors play a significant role in triggering the onset of GERD.

Nevertheless, the GERD diagnosis process still relies on conventional methods such as medical interviews, physical examinations, and supporting tests like endoscopy and pH-metry. Although these procedures are considered accurate, they have various limitations, such as relatively high examination costs, long waiting times due to patient queues, and limited medical facilities in remote areas. Furthermore, the subjectivity of patients in describing symptoms often creates uncertainty in diagnosis, risking delayed treatment. This situation emphasizes the need for alternative solutions that can provide initial diagnostic results quickly, efficiently, and accessibly, allowing patients to receive medical attention promptly before symptoms worsen. With technological advancements, artificial intelligence (AI) is increasingly being applied

in the health sector, including in medical expert systems. Expert systems allow a clinician's knowledge to be represented in the form of rules, which are then used to assist in diagnostic decision-making.

One widely used method is the Fuzzy Inference System (FIS), which can manage uncertain linguistic data. Rizky Baskara et al. (2022) developed an Android-based application using the Tsukamoto fuzzy method for diagnosing digestive tract diseases using input symptoms like nausea, epigastric pain, and regurgitation. That system showed an accuracy rate of 80%, confirming the effectiveness of the fuzzy approach in handling ambiguous medical data.

Based on the weaknesses of conventional diagnosis and the potential of fuzzy logic in expert systems, this research proposes the development of an expert system based on Mamdani fuzzy logic to assist in the initial diagnosis of GERD. The Mamdani method was chosen because it produces output in linguistic form, which is easier for medical practitioners to understand compared to other fuzzy methods. In this system, each symptom is converted into fuzzy sets (mild, moderate, severe) and processed through IF-THEN rules sourced from the medical knowledge of the practitioner. Subsequently, the defuzzification process using the centroid method is used to produce output in the form of the likelihood level of GERD. With this system, patients can perform initial detection without fully relying on direct consultation with a doctor, thereby saving time, reducing initial examination costs, and expanding public access to healthcare services.

2. LITERATURE REVIEW

2.1. Gastroesophageal Reflux Disease (GERD)

Gastroesophageal Reflux Disease (GERD) is a digestive tract disorder that occurs due to the reflux of stomach contents into the esophagus, causing irritating symptoms and long-term complications. The Montreal definition describes GERD as a condition with troublesome symptoms caused by the reflux of stomach contents into the esophagus (Chhabra & Ingole, 2022).

GERD management involves lifestyle changes, pharmacological treatments such as PPIs, and in some cases, surgical intervention. Risk factors such as obesity, high-fat diets, and stress also worsen this condition. In developing expert systems or artificial intelligence models, information related to symptoms and patient history is crucial to assist the process of early diagnosis efficiently and effectively (Chhabra & Ingole, 2022).

2.2. Conventional Diagnosis of GERD

The diagnosis of Gastroesophageal Reflux Disease (GERD) in conventional medical practice is generally carried out through a combination of anamnesis, clinical examination, and supporting investigations. The initial stage usually involves anamnesis, a medical interview regarding typical patient complaints such as epigastric pain, chest burning sensation (heartburn), nausea, and regurgitation. Although important, this method has limitations because it heavily depends on the patient's subjectivity in explaining the symptoms felt, which can affect diagnostic accuracy.

Furthermore, endoscopy is often used to evaluate the condition of the esophageal mucosa and identify the presence of esophagitis, strictures, or other complications due to acid reflux. Another method considered the gold standard is 24-hour pH-metry, which measures acidity levels in the esophagus to assess reflux frequency. Additional examinations such as esophageal manometry can also be performed to assess the function of the lower esophageal sphincter and esophageal motility patterns.

Although these techniques are proven accurate, obstacles remain. Endoscopy and pH-metry generally require high costs, long waiting times, and are not available in all healthcare facilities, especially in remote areas. This means most patients are only diagnosed after symptoms have progressed further, ultimately increasing the risk of complications. This situation underscores the importance of developing alternative solutions that can facilitate early detection of GERD in a faster, more affordable, and more accessible way for the public

2.3. Fuzzy Logic in Medical Expert Systems

Fuzzy logic is an approach in soft computing used to transform inputs into outputs that suit needs. Its advantages lie in the simplicity of its mathematical concepts, flexibility of use, tolerance for imprecise data, and its ability to model complex non-linear functions. This approach also allows for the adoption of expert experience without a training process, can be combined with conventional control methods, and is based on

natural language, making it closer to human thinking. Important components in its application are the fuzzy inference system, which works with fuzzy set theory, IF-THEN rules, and fuzzy reasoning mechanisms, useful for knowledge representation and interaction modeling (Saelan, n.d.). In medical practice, fuzzy logic is often implemented through expert systems, a form of artificial intelligence that mimics an expert's way of thinking by relying on a knowledge base, inference engine, and user interface. This system can analyze symptoms and provide an initial diagnosis based on medical rules, thus speeding up the decision-making process, especially for complex diseases like Gastroesophageal Reflux Disease (GERD) (Santoso & Kom, 2023).

2.4. Review of Previous Research

Various previous studies have shown the use of expert systems and fuzzy logic in assisting disease diagnosis. Maradona (2021) developed an expert system for diagnosing heart disease using the Case Based Reasoning (CBR) method. The system implementation results showed that the CBR method could help the public perform early identification of heart disease symptoms before undergoing further medical examination. Another study by Elly Yanti et al. (2023) developed an expert system for diagnosing human skin diseases using certainty factors. The implementation results showed that the system checks and accumulates the percentage values of all possible largest diagnoses according to the user's answers to draw conclusions. This system showed an accuracy rate of 74.1% from 15 test data points, matching the results given by the expert. Furthermore, Septiani et al. (2023) developed an expert system for ear diseases using Naïve Bayes; the implementation results showed the accuracy of the system's diagnosis results compared to the doctor's diagnosis was 90% correct from trials on 10 patients. Thomas Andrew Imanzaghi et al. (2025) developed an expert system using Mamdani fuzzy for diagnosing dengue fever, showing the system can contribute to the identification of dengue fever. In the development process of the dengue fever diagnosis system applying the Mamdani fuzzy method, testing was conducted, namely blackbox and confusion matrix. The confusion matrix test results obtained an accuracy of 92.8%. The average precision value was 90.6%, recall reached 95.8%, and the F1 Score was 92.6%.

From previous research, it appears that the application of fuzzy-based expert systems is quite widespread for various diseases, such as heart disease, hepatitis, dengue fever, and pulmonary TB. However, not much research has specifically focused on Gastroesophageal Reflux Disease (GERD), even though this disease often occurs in the community with symptoms similar to other digestive disorders. This condition creates a research gap that forms the basis of this study, namely presenting a Mamdani fuzzy-based expert system focused on the early diagnosis of GERD. With this approach, it is hoped to provide a faster, more economical, and more accessible solution for patients in detecting GERD early.

3. RESEARCH METHOD

This research applies a quantitative descriptive approach with the aim of designing and implementing an expert system based on Mamdani fuzzy logic to support the diagnosis process of GERD. The research object was conducted at the Practice of dr. Rumbang Sembiring, Sp.PD, which served as the data source and medical reference. The data used consisted of 200 patient medical records containing GERD-related symptoms and the results of diagnoses by an internist. This data was processed into a knowledge base and formulated in the form of inference rules. The analysis method applied was forward chaining inference with the Mamdani fuzzy approach. The research activity flow is depicted in Figure 1 as the research framework.

Framework Reasearch

3.1. Data Collection

Research data was collected through interviews and direct observation with an internist, namely dr. Rumbang Sembiring, Sp.PD. From this process, a list of symptoms often experienced by GERD patients was obtained. This symptom data was used as the basis for building the knowledge base in the Mamdani fuzzy-based expert system. Data collection was carried out systematically to ensure the information obtained was accurate and in accordance with the patient's clinical condition. The collected data was then used in the fuzzy inference process to produce more precise diagnostic results. Furthermore, each patient symptom was given an intensity weight on a scale of 0-10. This range was maintained to ensure diagnostic results were representative and not biased towards variations in patient symptoms. This scale was grouped into three severity level categories, namely:

Ringan (0, 2, 4)
Sedang (3, 5, 7)
Berat (6, 8, 10)

Kategorisasi ini digunakan dalam pembentukan fungsi keanggotaan fuzzy. Dengan adanya pembagian kategori ini, sistem dapat menilai tingkat keparahan gejala yang dialami pasien secara lebih terukur.\

1.1 Inferensi Forward Chaining

Forward Chaining Inference
The inference process is an important stage in the expert system for drawing conclusions based on facts provided by the user. In this expert system, the inference method used is Forward Chaining, which works by tracing symptom data from the patient towards a diagnostic conclusion based on predefined fuzzy rules.
The forward chaining method begins by collecting initial symptoms from the patient, which are symptom intensity scores (scale 1-10). Each symptom is converted into a fuzzy membership value representing the mild, moderate, or severe category. Then, the system will match these facts with the fuzzy rules available in the knowledge base.

Design of the Fuzzy Expert System

Mamdani Fuzzy Logic is a rule-based decision-making method used to model uncertainty and subjective judgment. This method is designed to mimic human thinking by utilizing linguistic logic in the form of IF-THEN rules. In expert systems, the Mamdani method is very effective in handling uncertain medical symptom data, such as levels of nausea, epigastric pain, and regurgitation, which are generally described by patients in qualitative terms.

In this research, the Mamdani fuzzy method is used to design an expert system capable of diagnosing the possibility of GERD based on a combination of symptoms input by the patient or doctor. The diagnostic process is carried out through several stages: fuzzification of input values, application of fuzzy rules (inference), aggregation of inference results, and defuzzification to produce output in the form of a crisp value indicating the level of GERD likelihood. This output is then classified into linguistic categories: low, medium, or high.

The formula used in the defuzzification stage is the center of gravity (centroid) method, expressed as follows:

$$z = \frac{\sum z_i * \mu(z_i)}{\sum \mu(z_i)}$$

Di mana z merupakan output akhir, zi adalah nilai pada domain output, dan μ(zi)\mu(z_i)μ(zi) merupakan
derajat keanggotaan fuzzy dari nilai tersebut.

1.2 Evaluasi Keluaran Sistem

System Output Evaluation The system output evaluation aims to assess the level of agreement between the expert system's diagnostic results and the actual diagnosis from the doctor treating the patient at the practice of dr. Rumbang Sembiring, Sp.PD. The evaluation process is carried out by comparing the classification results of the Mamdani fuzzy system with the diagnostic data available in the patient's medical records. evaluation was done manually by matching each system output against the doctor's diagnosis. If the system's result and the doctor's diagnosis matched (e.g., both indicated GERD), it was considered a match. If not, it was recorded as a mismatch.

$$Akurasi\ (\%) = \frac{Jumlah\ data\ yang\ cocok}{Data\ Uji} X\ 100$$

Hasil evaluasi ini memberikan gambaran seberapa baik sistem pakar yang dirancang mampu merepresentasikan pengetahuan pakar dalam proses identifikasi kemungkinan GERD. Evaluasi juga dapat menjadi dasar untuk perbaikan aturan fuzzy atau penyesuaian fungsi keanggotaan apabila sistem menunjukkan ketidaksesuaian yang signifikan.

3.5. System Design

In this research, system design was carried out using UML and the PHP and Python programming languages. In the development process of this system, the author utilized four (4) diagrams: use case diagram, activity diagram, class diagram, and sequence diagram.

4. RESULTS AND DISCUSSION

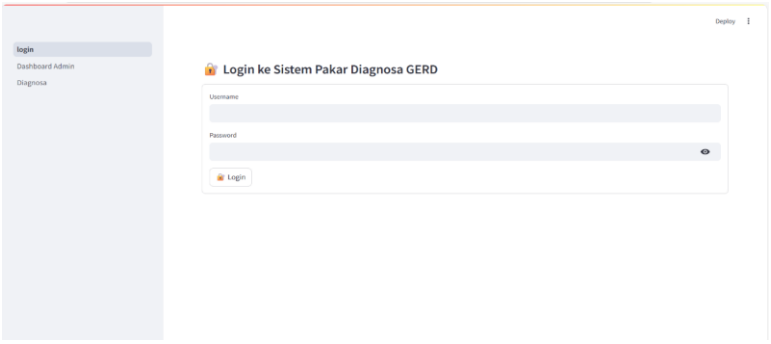
The results of this research show that the developed web-based expert system can diagnose Gastroesophageal Reflux Disease (GERD) using the Mamdani fuzzy method. System implementation was carried out through the collection of symptom data, design of fuzzy rules, and application of the inference process to produce a diagnosis that matches the patient's condition. Testing was conducted on patient data to assess the accuracy and effectiveness of the system in supporting the identification of GERD symptoms.
Furthermore, this research provides novelty by directing the application of the expert system specifically to the case of GERD intervention, resulting in a more focused and relevant diagnostic approach for medical practice.

System Implementation

The expert system for diagnosing Gastroesophageal Reflux Disease (GERD) was developed using the Python programming language with the Streamlit framework. This framework was chosen because it supports the creation of interactive web interfaces and is easily integrated with the Mamdani fuzzy method. System implementation is divided into several main parts.

4.2. Login Page

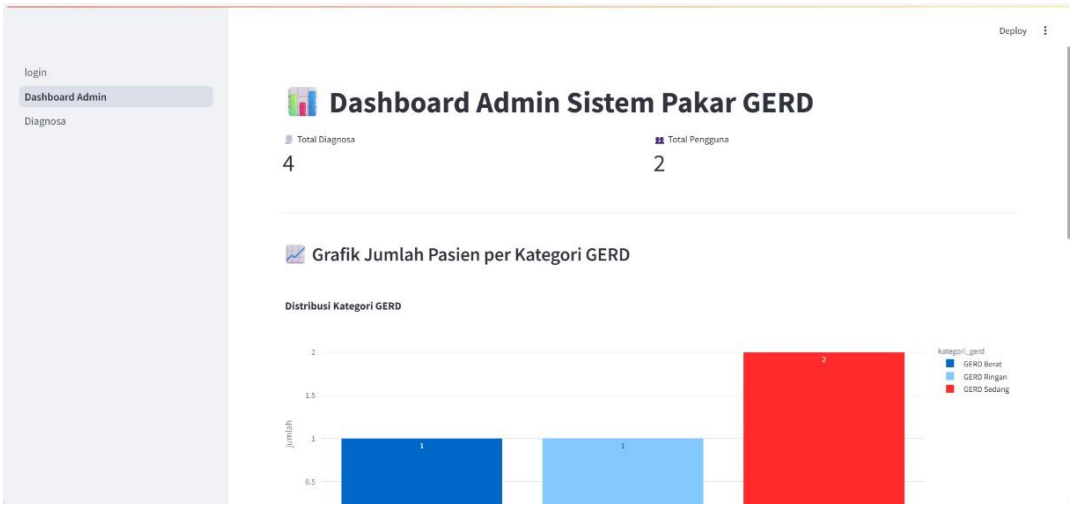
The login page functions as the initial authentication mechanism. Users are required to enter a username and password to access the system, either as a user or an admin.



Gambar 2 Tampilan halaman login

4.3. Dashboard Page

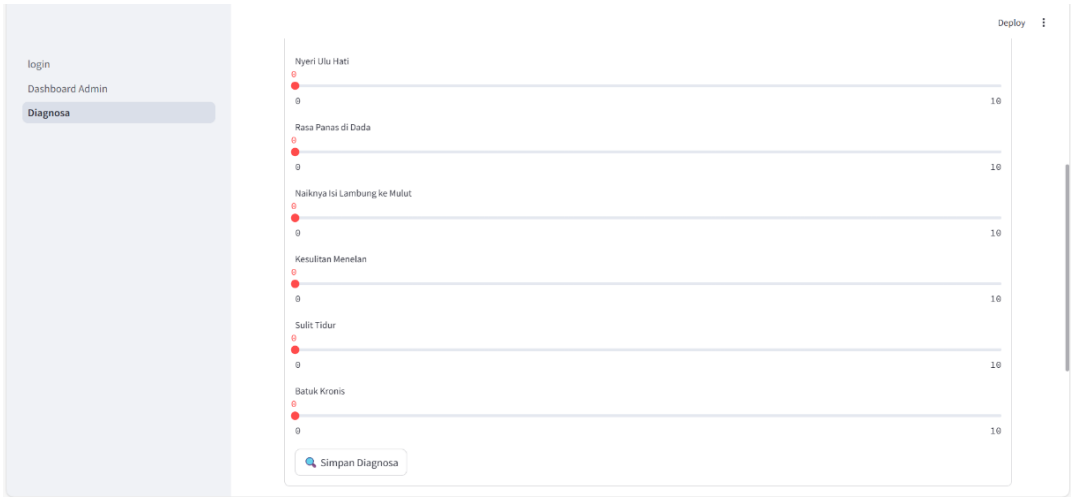
After successful login, the user is directed to the dashboard page. This page presents a summary of information and navigation to the main menus, such as Diagnosis, Diagnosis History, and Symptom Data Management. On the admin account, the dashboard also displays summary data on the number of symptoms and a record of diagnosis history.



Gambar 3 Tampilan halaman *dashboard*

Diagnosis Page

The diagnosis page is the core part of the system. Users can select experienced GERD symptoms from the available list. Each symptom has a weight value with mild, moderate, or severe categories. This data is processed using Mamdani fuzzy inference to produce the level of GERD possibility.



Gambar 4 Tampilan halaman diagnosa

Diagnosis History Page

This page presents a record of previous diagnosis results, including the examination date, selected symptoms, and diagnosis results. This feature supports the process of continuous patient condition monitoring.

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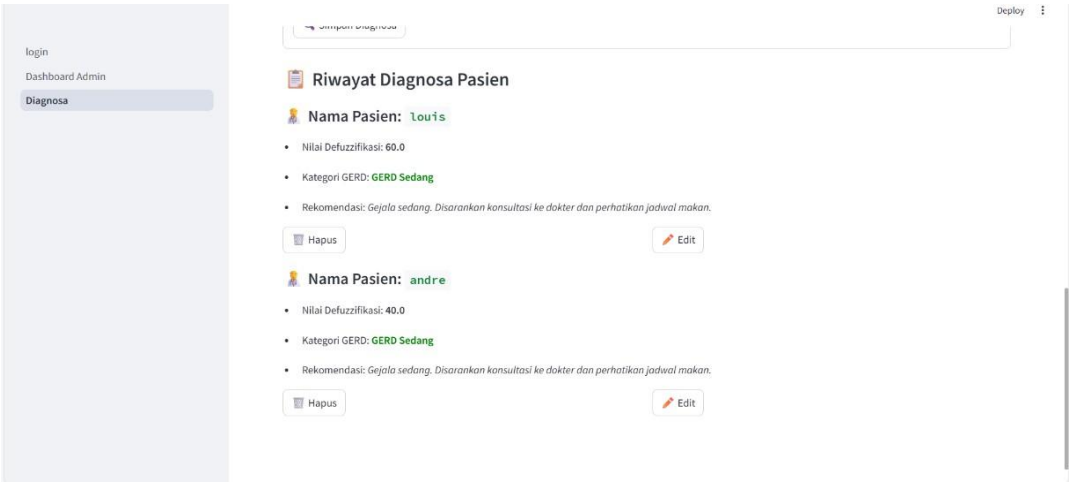
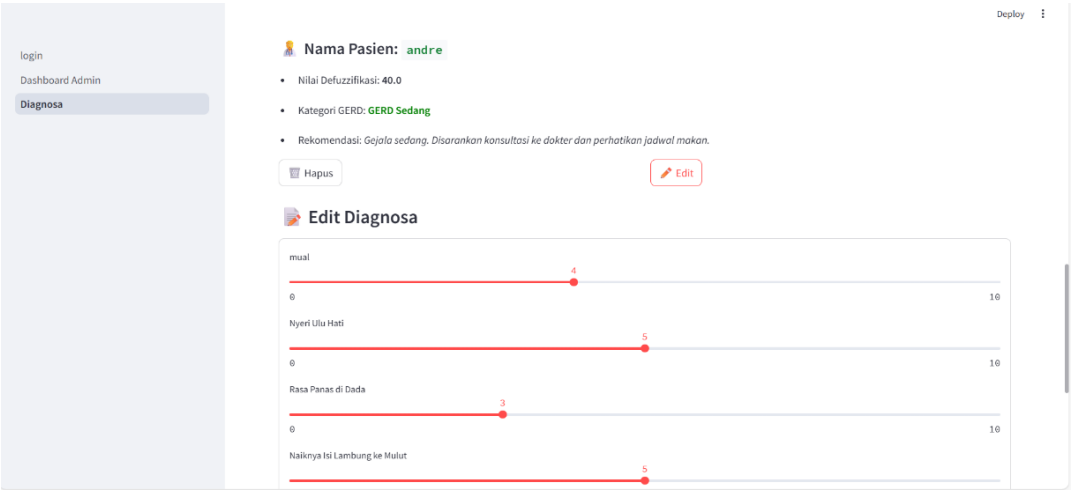


Gambar 5 Tampilan halaman riwayat diagnosa

4.6. Edit and Delete Page

The symptom data management page is available specifically for the admin. Through this page, the admin can add, change, or delete symptoms as needed. This feature ensures the system can be continuously updated following medical data developments.



Gambar 6 Tampilan halaman edit dan hapus

Comparison of Doctor and System Diagnosis Results

Evaluation was conducted using 40 patient data points from medical practice. Each patient's data was processed by the Mamdani fuzzy-based system, then the diagnostic results were compared with the results of the examination by the internist. This comparison is presented in a table containing the patient code, doctor's diagnosis, and system diagnosis.

No.	Kode Pasiean	Diagnosa Dokter	Diagnosa Sistem
1	14319	Gerd Ringan	Gerd Sedang
2	14340	Gerd Sedang	Gerd Sedang
3	14348	Gerd Sedang	Gerd Sedang
4	14352	Gerd Sedang	Gerd Sedang
5	14345	Gerd Sedang	Gerd Sedang
6	14361	Gerd Sedang	Gerd Sedang
7	14364	Gerd Sedang	Gerd Sedang
8	14368	Gerd Sedang	Gerd Sedang
9	13877	Gerd Sedang	Gerd Sedang
10	14700	Gerd Ringan	Gerd Sedang
11	14067	Gerd Sedang	Gerd Sedang
12	14062	Gerd Sedang	Gerd Sedang
13	14060	Gerd Sedang	Gerd Sedang
14	14054	Gerd Sedang	Gerd Ringan
15	14051	Gerd Ringan	Gerd Ringan
16	14050	Gerd Sedang	Gerd Sedang
17	14040	Gerd Sedang	Gerd Sedang
18	14039	Gerd Sedang	Gerd Sedang
19	14038	Gerd Sedang	Gerd Sedang
...	...	...	...
40	13831	Gerd Sedang	Gerd Sedang

$$Akurasi = \frac{x\ 100\%}{40}\ x\ 100\% = 87{,}5\%$$

2. Thus, the system has an accuracy of 87.5% compared to the doctor's diagnosis. This indicates that the Mamdani fuzzy-based expert system is quite reliable in providing diagnostic results, especially in cases of mild to moderate GERD which have more consistent symptom patterns. Differences in results occurred more frequently in cases of severe GERD, where the system tended to classify them as moderate categories due to the limitations of the fuzzy membership function. Therefore, the system can be used as an initial diagnostic aid, but the final decision remains with the doctor as a medical professional.

5. CONCLUSION AND SUGGESTIONS

5.1. Conclusion

Based on the research results and implementation of the Mamdani fuzzy-based GERD diagnosis expert system, it can be concluded that the system designed and implemented in the form of a website using the Mamdani fuzzy logic method is capable of assisting the initial diagnosis process of GERD quickly, accurately, and based on symptoms input by the user. The Mamdani fuzzy method proved effective in processing linguistic and uncertain symptom data into output in the form of an interpretative GERD likelihood level that conforms to medical reasoning rules. Furthermore, this system provides real benefits for medical personnel as it can reduce subjective assessment in initial diagnosis and contributes to the development of expert system technology in the health sector, particularly for digestive diseases like GERD. However, this research still has limitations, especially in the number of symptom parameters used and the relatively limited scope of patient data, thus requiring further development so that the system can produce increasingly accurate and representative diagnoses.

5.2. Suggestions

The development of this fuzzy logic-based GERD diagnosis expert system is expected to be continuously refined in the future. There is a need to add more symptom parameters and patient medical history data to improve the accuracy of diagnostic results. Furthermore, this system also has the potential to be integrated with a mobile application so that it can be accessed flexibly anytime and anywhere, thus its benefits can be broader for users and medical personnel. With these developments, this system is expected to be a more reliable, adaptive, and suitable diagnostic support solution for the needs of modern medical practice.

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