Fuzzy Knowledge-based System with Uncertainty for Tropical Infectious Disease Diagnosis

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Abstract

On the development of medical knowledge-based system, the inability of a patient in a complaint must be dealt with by the fuzzy logic method, while the inability of an expert in defining the relationship between the symptoms of the disease can be treated with certainty factor method. In this study, both methods were combined to make diagnosis of tropical infectious diseases. Knowledge acquired from medical specialist in internal medicine, with produce fact, a crisp and fuzzy symptoms, and rule with the certainty value of the specialist. Reasoning process starts from the implication, decomposition, defuzzification and certainty factor calculation. System developed on web based platform and provide a workplace, explanation facility and knowledge improvement. System testing is done to compare the results of specialist diagnosis and system diagnosis, which results of testing show the system, has similarity with the expert at 91.07%.

Keywords: *knowledge-based system, web based, fuzzy logic, certainty factor, a tropical infection.*

1. Introduction

Governance processes begins with anamnesis to get the fact about the patient's disease state, through interviews the patient and their family in addition physical examination to get the disease symptom. Through anamnesis and physical examination will summarize into relevant identities, symptoms of brief development and their signs. This summary will execute into basic list of the issues which is arranged on priority. Through this list of issues, some research will occurs to find out what will examiner has taken this issue into the list. Based on this research, planning of medical treatment procedure will take affect like support, therapy and counseling [1].

In fact, doctors do not fully follow the governance process described above. Anamnesis is made in haste without giving opportunity to the patient or patient's family to explain the situation. Physical examination is performed less often meticulous and detail. The result of anamnesis and physical examination performed by a doctor unable to give an idea how severe the illnesses suffered by the patient. This is because the similarity between the symptoms of a disease with other diseases that make a doctor to be able to determine the relationship between the symptoms experienced by the patient against possible illnesses.

This research will develop an expert system combines the method of Fuzzy Logic and Certainty Factors with the object of research is a disease of tropical infectious diseases include Dengue Fever, Typhoid Fever and Chikungunya. Fuzzy logic methods will be used to handle the uncertainty experienced the patient's symptoms and the certainty factor method will be used to handle the inability of an expert in defining the relationship between the symptoms of the disease with certainty. Expert system developed on web based platform, provide improve of knowledge, where expert can add new knowledge to a disease or alter the existing knowledge on the disease, so the system will remain accurate and up to date.

2. Previous Research

Researches related to expert systems in medicine have been done by using one method such as Certainty Factors or Fuzzy Logic, with several research objects as follows.

M. Abdel-Salem Badeeh and M. El Bagoury Bassant develop model of an expert system for diagnosis of diseases thyroid cancer by combining the methods of neural network and certainty factor. The model is constructed consisting of three phases, each phase using a single network for the learning process. The model was tested against 820 cases of thyroid cancer patients from the National Cancer Institute of Egypt. Through cross-validation tests showed the diagnostic performance rate that reaches 99.47% [2].

M. Ragab Abdul Hamid, Khalid Abdullah and Mohamed Ismail Fakeeh Roushdy develop expert systems for diagnosis of heart disease with certainty factor method. Heart disease is classified into 25 types of disease that is left heart failure and right heart failure in the form of semantic networks. Data is divided into patient demographic data (age and sex) and clinical data such as laboratory results and clinical examination. Knowledge representation is done by using production rules [3].

Emmanuil Marakakis, Kostas Vassilakis, Emmanuil Kalivianakis and Sifis Micheloyiannis develop expert systems for disease diagnosis of epilepsy with certainty factor method. Data used are 50 types of epilepsy, in which each type of epilepsy is expressed in the form of 28 diagnostic criteria. The knowledge obtained by physical examination and laboratory results. The system was tested against 42 cases in children with the test results are successfully entered correctly diagnosed 35 cases (83.3%) [4].

Neshat Mehdi and Yaghobi Mehdi develop expert systems for diagnosis of hepatitis B by comparing the method of Fuzzy Inference System (FIS) and Adaptive Neuro-Fuzzy Inference System (ANFIS). Case studies conducted at Imam Reza Hospital, Mashad Iran with 300 patient medical records, where each record consists of seven attributes. Inference methods used in the FIS is Mamdani method, while the ANFIS is a Sugeno method. Test results showed the success rate that reached 94.24% while the FIS ANFIS success rate reached 96.4 ± 0.2% [5].

Fazel Zarandi, Zolnori, Moin, and Heidarnejad develop expert systems for diagnosis of asthma disease by the method of Fuzzy Logic. The knowledge acquisition process is done by using a semantic network. Knowledge representation is done with the production rules. Fuzzy inference method used is the Mamdani method and the method used is defuzzification centroid method. Testing method used is a method of verification and validation. Test results on 53 patients with asthma and 53 non-asthmatic patients of Imam Khomeini Hospital and Masih Daneshvari in Tehran, Iran, with a cut-off value of 0.7 indicates the level of accuracy of 100% and 94% response rate [6].

Ali and Mehdi Adeli Neshat develop expert systems for diagnosis of heart disease by the method of Fuzzy Logic. The system uses 11 variables attributes input and one output variable attributes. Inference method used is the Mamdani and the defuzzification method used is centroid. Test results on 303 patients from V.A. Medical Center, Long Each and Cleveland Clinic Foundation showed that success rates of 94% of these systems [7].

3. The Advantages of Medical Expert System

Technology development is adopted to ease the communication between doctor and patient to increase of the services according to governance procedures. Expert system is one outgrowth of technology developed with the aim to mimic the ability of an expert in a particular field [8]. Expert system enables the communication process between doctor and patient can be done without having to directly face to face.

Users will be directed by the system to deliver the complaint in detail and gradually. Expert system will provide solutions to the complaints submitted by users. In fact, expert systems capable of providing solutions to problems contain elements of uncertainty such as the similarity between the symptoms of a disease with other diseases. Capabilities provided by the expert system is a solution to overcome that often the problems occur in the governance process of the patient, especially if it is developed for people who are in areas that do not have a doctor with specific expertise. Expert systems will be a guide for the health services available to rapidly determine the governance of a patient.

4. Methodology

4.1 Knowledge Acquisition

Based on literature studies and interviews with expert, the knowledge obtained for the above seven diseases, including the gender of the patient, physical symptoms, syndrome symptoms and symptoms of laboratory results. Physical examination consists of 22 symptoms, syndrome consists of 6 symptoms and results of the laboratory consist of 6 symptoms [9]-[11].

4.2 Knowledge Representation

Based on the above knowledge acquisition, the determination of input variables for expert systems will be developed by proposing a fuzzy set with membership function [12]-[14]. On physical examination, there are 5 symptoms of fuzzy value. On the results of laboratory, there are 6 symptoms of fuzzy value. From 11 symptoms of fuzzy value, some of fuzzy sets model are shown below.

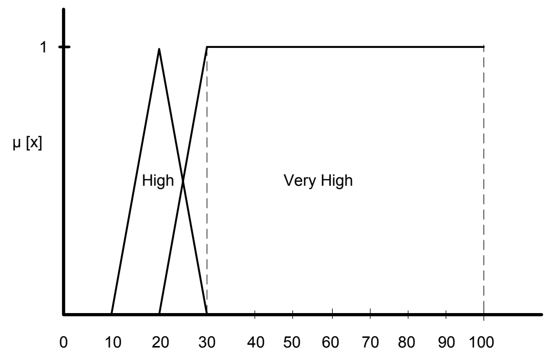

Fig. 1 Membership curve of tourniquet test

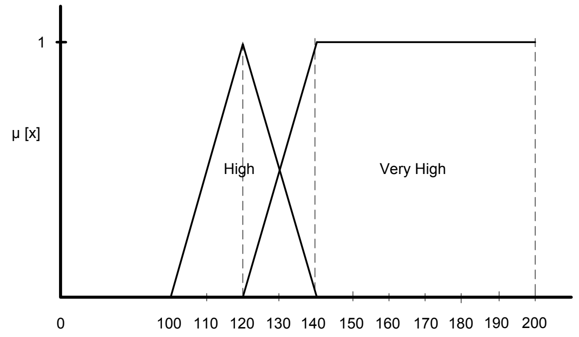

Fig. 2 Membership curve of pulse

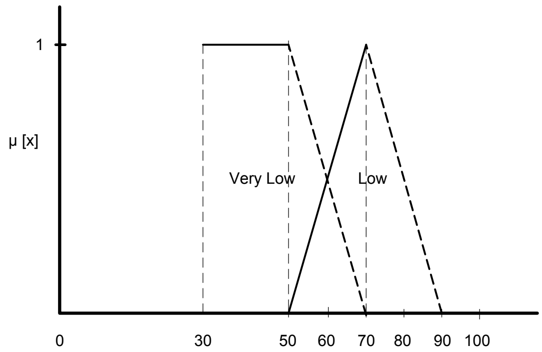

Fig. 3 Membership curve of systolic blood pressure

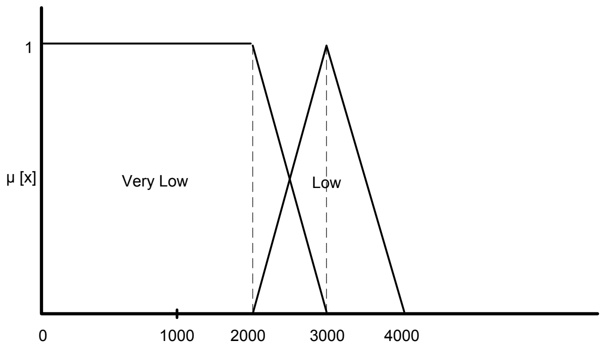

Fig. 4 Membership curve of leukocyte for adult male

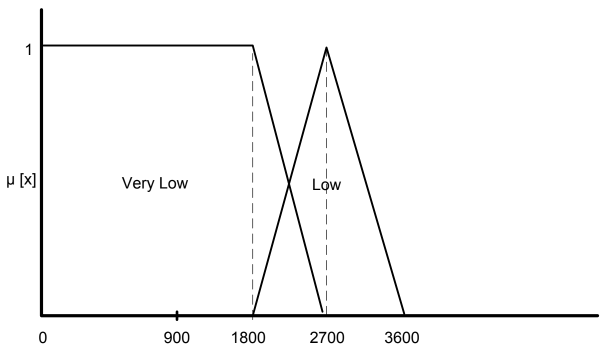

Fig. 5 Membership curve of leukocyte for adult female

Membership functions of tourniquet test:

$$\mu_{High}(x) = \begin{cases} \frac{x-10}{10}, & 10 \leq x \leq 20 \\ 1, & x = 20 \\ \frac{30-x}{10}, & 20 \leq x \leq 30 \end{cases}$$

$$\mu_{VeryHigh}(x) = \begin{cases} \frac{x-20}{10}, & 20 \leq x \leq 30 \\ 1, & x \geq 30 \end{cases} \quad (1)$$

Membership functions of pulse:

$$\mu_{High}(x) = \begin{cases} \frac{x-100}{20}, & 100 \leq x \leq 120 \\ 1, & x = 120 \\ \frac{140-x}{20}, & 120 \leq x \leq 140 \end{cases}$$

$$\mu_{VeryHigh}(x) = \begin{cases} \frac{x-120}{20}, & 120 \leq x \leq 140 \\ 1, & x \geq 140 \end{cases} \quad (2)$$

Membership functions of systolic blood pressure:

$$\mu_{VeryLow}(x) = \begin{cases} \frac{70-x}{20}, & 50 \leq x \leq 70 \\ 1, & x \leq 50 \end{cases}$$

$$\mu_{Low}(x) = \begin{cases} \frac{x-50}{20}, & 50 \leq x \leq 70 \\ 1, & x = 70 \\ \frac{90-x}{20}, & 70 \leq x \leq 90 \end{cases} \quad (3)$$

Membership functions of leukocyte for adult male:

$$\mu_{VeryLow}(x) = \begin{cases} \frac{3000-x}{1000}, & 2000 \leq x \leq 3000 \\ 1, & x \leq 2000 \end{cases}$$

$$\mu_{Low}(x) = \begin{cases} \frac{x-2000}{1000}, & 2000 \leq x \leq 3000 \\ 1, & x = 3000 \\ \frac{4000-x}{1000}, & 3000 \leq x \leq 4000 \end{cases} \quad (4)$$

Membership functions of leukocyte for adult female:

$$\mu_{VeryLow}(x) = \begin{cases} \frac{2700-x}{900}, & 1800 \leq x \leq 2700 \\ 1, & x \leq 1800 \end{cases}$$

$$\mu_{Low}(x) = \begin{cases} \frac{x-1800}{900}, & 1800 \leq x \leq 2700 \\ 1, & x = 2700 \\ \frac{3600-x}{900}, & 2700 \leq x \leq 3600 \end{cases} \quad (5)$$

4.3 Fuzzy Inference

Fuzzy reasoning process begins by performing a fuzzy rule-making based on knowledge representation. Fuzzy rule is formed by combining some of the same symptoms for several diseases. Combined symptoms in this study referred to by the term "syndrome", to distinguish it from a single symptom.

Rules are made for the expert system developed as much as 841 rules, which consists of 32 rules for Dengue Fever, 47 rules for Dengue Hemorrhagic Fever I, 50 rules for Dengue Hemorrhagic Fever II, 82 rules for Dengue Hemorrhagic Fever III, 62 rules for the Dengue Hemorrhagic Fever IV, 199 rule for Chikungunya and 369 rules for Typhoid Fever. Conclusions contained in any rule requiring the confidence of expert (Expert CF) to determine how much the belief that the symptoms affecting the diagnosis occurred at the conclusion. Some of the rules produced are shown in Table 1.

Calculation of the degree of fuzzy membership for each symptom is determined by the value assigned by the user. For example, if user types the body temperature is 39^0C and 'Yes' for temperature less than one degree.

$$\mu_{increased\_temperature=High}(39) = \frac{39.5-39}{1.0} = \frac{0.5}{1.0} = 0.50$$

$$\mu_{increased\_temperature=VeryHigh}(39) = \frac{39-38.5}{1.0} = \frac{0.5}{1.0} = 0.50$$

Based on the degree of membership, calculate the implication function with MIN function [12]-[14]. $\mu(x)$ is the degree of membership for x and w_i is the result of implication.

$$wi = Min(\mu(x), \mu(y)) \tag{6}$$

Table 1: Fuzzy rule

No.	Rules
1	**IF**(increased_temperature = NO) **AND** (temperature_ difference_less_than_one_degree = YES) **THEN CF: 0.70**
2	**IF**(increased_temperature = HIGH) **AND** (temperature_ difference_less_than_one_degree = YES) **THEN CF: 0.85**
3	**IF**(increased_temperature = VERY HIGH) **AND** (temperature_ difference_less_than_one_degree = YES) **THEN CF: 0.90**
4	**IF**(increased_temperature = NO) **AND** (temperature_ difference_less_than_one_degree = NO) **THEN CF: 0.50**
838	**IF**(thrombocytopenia = LOW) **AND** (lymphopenia = VERY LOW) **AND** (erythrocyte_sedimentation_rate_increased = VERY HIGH) **AND** (leukocytosis = VERY HIGH) **AND** (anemia = LOW) **THEN CF: 0.52**
839	**IF**(thrombocytopenia = NO) **AND** (lymphopenia = LOW) **AND** (erythrocyte_sedimentation_rate_increased = VERY HIGH) **AND** (leukocytosis = VERY HIGH) **AND** (anemia = LOW) **THEN CF: 0.56**
840	**IF**(thrombocytopenia = VERY LOW) **AND** (lymphopenia = LOW) **AND** (erythrocyte_sedimentation_rate_increased = VERY HIGH) **AND** (leukocytosis = VERY HIGH) **AND** (anemia = LOW) **THEN CF: 0.54**
841	**IF**(thrombocytopenia = LOW) **AND** (lymphopenia = LOW) **AND** (erythrocyte_sedimentation_rate_increased = VERY HIGH) **AND** (leukocytosis = VERY HIGH) **AND** (anemia = LOW) **THEN CF: 0.55**

For the example above, the implication result is shown below.

w_1 = min($\mu_{BodyTemperature=High}$[39], $_{Temperature<1=Yes}$)
= min(0.50, 1.0) = 0.50
w_2 = min($\mu_{BodyTemperature=VeryHigh}$[39] , $_{Temperature<1=Yes}$)
= min(0.50, 0.1) = 0.50

The process of composition is made to obtain the value z_i of each rule. The expert confidence value of each rule is value of z_i. The rules of body temperature for both fuzzy sets are shown below.

A00000002, CF: 0.85
A00000003, CF: 0.90

Defuzzification process is done using weighted average method defuzzification by calculating the average value of zi [12]-[14].

$$Final\ Result = \frac{\sum_{i=1}^{N} w_i z_i}{\sum_{i=1}^{N} w_i} \tag{7}$$

w_i is the result of implication and z_i is the result of composition. The results of defuzzification demonstrate the value of the belief for the syndrome experienced by patients. For the example above, the defuzzification result is shown below.

$$z = \frac{(0.5*0.85)+(0.5*0.9)}{0.85+0.9} = \frac{0.875}{1.75} = 0.50$$

4.4 Certainty Factor Calculation

The result of defuzzification process will be used to calculate the value of belief for the diagnosis. Firstly, will be calculated certainty factor (CF) sequential as follows [13].

$$CF(x,y) = CF(x) * CF(y) \tag{8}$$

CF(x,y) is result of certainty factor sequential, CF(x) is result of defuzzification and CF(y) is the expert confidence value of each rule. CF sequential from several rules generated combined using the following calculation of the combined CF as follows [13].

$$CF(x,y) = CF(x) + CF(y) - (CF(x) * CF(y)) \tag{9}$$

For the example above, the calculation result is shown below.

$$CF(x,y)\ A00000002 = 0.50 * 0.85 = 0.43$$
$$CF(x,y)\ A00000003 = 0.50 * 0.90 = 0.45$$

The results of combined CF suggest the diagnosis of the disease to the symptoms experienced by patients.

$$CF(x,y) = 0.43 + 0.45 - (0.43 * 0.45) = 0.69$$

5. Implementation

5.1 Knowledge Base Design

Knowledge base built in the form of 13 tables, such as table of status, table of sets, table of curves, table of diseases, table of symptoms, table of fuzzy symptoms, table of disease symptoms, table of response options, table of syndrome, table of detailed syndromes, table of rules and table of detailed rules. The relationship between the tables is shown at Figure 6.

5.2 Inference Base Design

Inference base built in the form of 6 tables, such as table of diagnosis, table of consultation, table of detailed consultation, table of membership and table of implication. The relationship between the tables is shown at Figure 7.

5.3 System Platform

Expert system developed on web based platform using some software such as SQLyog Community Edition to build knowledge base, Macromedia Dreamweaver 8 with PHP and Java Script to build the application, and CSS to design the interface.

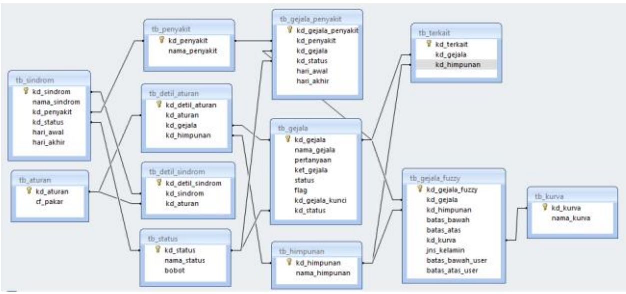

Fig. 6 Relationship of knowledge base

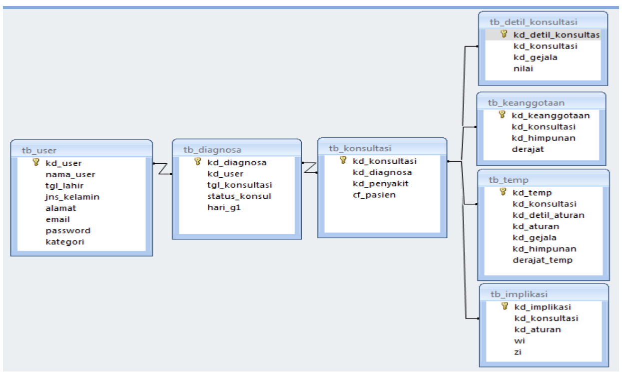

Fig. 7 Relationship of inference base

5.4 System Structure

Knowledge engineer can acquire the knowledge from the expert by using user interface facility in the system.

Knowledge base used by the knowledge engineer to represent the knowledge that gained from the acquisition of knowledge. The fact are the disease, the symptoms, the phase of disease, the fuzzy symptoms, the curve, the fuzzy sets, the symptoms of diseases and user response options. The rules are made by combining the facts above.

The interface is an environmental consultancy that is intended for users to do the questions and answers with the expert system. The answer to the symptom of crisp value is given in two options ('No' and 'Yes'), and the answer to the symptom of fuzzy value is given in a numeric value.

The inference engine uses IF-THEN production rules, the reasoning method of Forward Chaining. Reasoning based on rules that have been established on the basis of knowledge above.

Workplace in the developed expert system represented in the form of inference base above. Improvement of knowledge can be done if there are additions or changes to the knowledge. Based on any additions or changes, the system will do the creation of new rules of the syndrome and the diseases that generate automatically. The example for this facility is shown at Figure 8.

5.5 Consultation Case

Based on the structure of the above system, the expert system was tested on 20 different cases. One example of consultation and the diagnosis of the system are given at Table 2 and Figure 9.

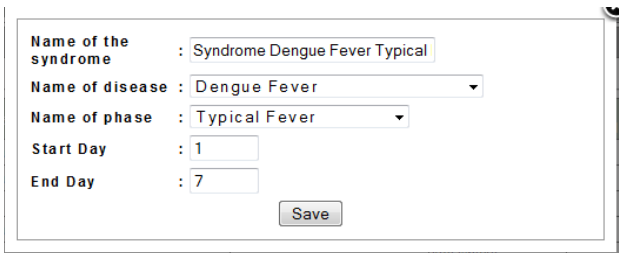

Fig. 8 Knowledge improvement interface

Table 2: Consultation Example

No.	Questions	Answer
1	Are you experiencing an increase in body temperature from normal temperature? If so, what is your body temperature when measured using a thermometer?	39^{0}C
2	Does every time you make a measurement of temperature with a thermometer, an increase/decrease in temperature that occurred less than one degree?	Yes
3	Do you feel pain in the head?	Yes
4	Do you feel pain in the spine?	Yes
5	Do you feel pain in the back of the eye?	Yes
6	Do you feel pain in the muscles?	Yes
7	Do you feel pain in joints?	Yes
8	Do you feel joint pain tends to occur in the morning?	No
9	Do you feel joint pain feels inclined to move or do not settle on a particular limb?	No
10	Do you feel joint pain in the ankle?	No
11	Do you feel joint pain in the wrist?	No
12	Do you feel joint pain occurs in the joints of the hands?	No
13	Do you have a rash on the skin?	No
14	Do you have vomiting?	No
15	Does every time you make a measurement of temperature with a thermometer, decrease in temperature that occurs to achieve normal body temperature?	Yes
16	Does every time you make a measurement of temperature with a thermometer, an increase / decrease in temperature that occurs to achieve two degrees?	No
17	Do you feel headache?	No
18	Are you experiencing an increase in temperature from normal temperature, especially in the afternoon until the evening?	No
19	Are you experiencing loss of appetite?	No
20	Do you have nausea?	No
21	Does your stomach feel uncomfortable and bloated?	No
22	Are you having difficulty in bowel movements or diarrhea?	No

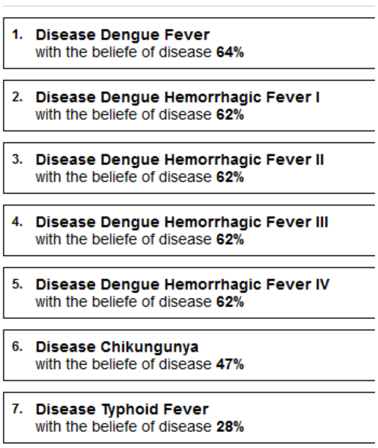

Fig. 9 Result of diagnosis

6. System Performance

Developed an expert system testing performed by comparing the results of diagnosis made by a real expert with the diagnosis given by the expert system. Table 3 shows that system performance as the result of the comparison.

The difference result between expert diagnosis and system diagnosis for the case is 8.93%, indicates that the expert system have similarity with the real expert at 91.07%. This is because the expert system developed using a fuzzy set to some of the symptoms so that can handle the vagueness of existing symptoms, as well as the believe value of an expert on the relationship of symptoms to be able to handle the uncertainty of the diagnosis is given.

7. Conclusion and Future Work

Expert system for diagnosing tropical infectious diseases has been developed on web based platform to receive input in the form of physical symptoms and results of complete blood examination in the laboratory. The inputs are crisp and fuzzy value to handle the vagueness of symptoms. Fuzzy rules represent the relationship of symptoms of each disease using the certainty of the expert. The system provides output from the diagnosis of the seven existing disease expressed as a percentage of certainty of the user experience of the disease. Test results show that the system developed has the similarity with the real expert at 91.07%. This research can be developed in the future by adding other components such as laboratory examination of a more specific follow-up. In addition, research can be developed also to the possibility of secondary infection of any disease, so the results are given more accurate diagnosis.

Table 3: System performance

Case	Expert Diagnosis (%)	System Diagnosis (%)	Difference (%)
1	54	55	1.84
2	54	57	4.47
3	56	60	6.92
4	60	61	0.95
5	51	62	21.11
6	59	65	10.24
7	61	69	13.41
8	51	61	19.44
9	64	65	1.78
10	66	71	7.53
11	56	64	15.13
12	66	71	7.53
13	56	65	17.44
14	66	71	7.53
15	57	65	13.50
16	59	63	7.32
17	60	64	6.43
18	7	7	0.00
19	24	26	8.82
20	26	28	7.22
Average of Difference			8.93

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