Implementation of Fuzzy Expert System on Skin Diseases

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***Abstract*—Skin diseases are a group of diseases affecting people of all ages, commonly caused by fungi, bacteria, parasites, viruses, and infections. The disease's main symptoms are usually itching all over the skin. Many patients are often underestimated and embarrassed to consult directly with doctors, which in the end, ignores the symptoms of skin diseases. Since they usually have imprecision symptoms, examining skin diseases is complex and challenging. Recently, many efforts have been made to utilize artificial intelligence approaches for diagnosing various diseases based on the patient's condition. This paper aims to develop a novel fuzzy-based medical expert system based on unprecise existing symptoms. The system uses the specialist Doctor's knowledge (dermatologist) to diagnose and provide the patient's severity level for the disease. We have done numerical experiments using 100 (one hundred) test problems to evaluate the performance of the developed system by comparing the result with the recommendations of doctors (dermatologists). It shows that this system succeeds in all tests with an accuracy value of 95.6%. Thus, this system is very beneficial to support doctors in the assessment of skin diseases.**

Keywords*—Artificial intelligence; expert system; fuzzy logic; skin disease

I. Introduction

The skin is the human body's largest organ [1]. Bacteria, viruses, or fungi have usually caused several types of diseases. The statistics indicate that skin diseases are common in half the adult population [2]. In Indonesia, patients with skin diseases are 62.8% men and 37.2% women. With details of the age group 11-20 years 31.4%, in the age group 21-30 years 19.3%, in the age group 31-40 years 14.6% with 76 cases, in the age group 41 -50 years 11.3%, in the age group 51-60 years 7.5%, and the age group > 60 years 3.1%, and the last one in the age group < 10 years 12,8% [3]. Treating skin disease reduces the most negligible effect of disrupting a patient's life quality. Doctors and paramedics often see patients with severe skin diseases without proper treatment. Many patients are often underestimated and embarrassed to consult directly with doctors, which in the end, ignores the symptoms of skin diseases.

Correctly diagnosing a skin disease is essential to patient-centered care. It requires knowledge and thoroughness from expert doctors, but doctors have limitations in consulting with patients because of the tight schedule and many patients. In addition, patients are sometimes embarrassed to consult directly with the Doctor. Many patients underestimate this skin disease, which in the end ignores the symptoms of skin disease.

The treatment therapy given to patients is usually done by giving medicine. Providing the appropriate drugs and the proper dosage is critical for skin disease medication and requires the standard knowledge of pharmacology. Inappropriate or improper dosage would become health problems, such as increased side effects, treatment failure, and resistance [4].

Recently, as computers have become popular, many researchers have developed technology in the form of artificial intelligence that imitates an expert's ability (based on expert knowledge) to make decisions. Expert systems use an expert's knowledge to solve some of our real-life activities, including Interpretation, Prediction, Diagnosis, Design, Planning, Monitoring, and so on [5]-[6]. In medical science, expert systems have been adopted to help doctors and specialists diagnose and get appropriate advice on several medical problems, such as Teeth and Gums, Shortness of Breath in Infants and Children, Eye Diseases, breast cancer, neck pain, and Anemia Diseases. With this expert system, even ordinary people can solve complex issues that usually can only be solved with the help of experts [7].

Each year we see almost ten billion Google Searches related to skin, nail, and hair issues. Two billion people worldwide suffer from dermatologic issues, but there's a global shortage of specialists. While many people's first step involves going to a Google Search bar, it can be challenging to describe what you see on your skin through words alone. Patients consider skin disease a common disease because there is no information about the causes and indications of the disease known to the patient [8]. Many patients experience the adverse effects of skin disease without realizing it, so experts in diagnosing kidney disease are needed. However, because the time specialists have is very limited and the number of patients is large, it is difficult for patients to consult a specialist. It causes patients and specialists to have difficulty conveying information about skin diseases. Therefore, people need an expert system that helps to analyze skin diseases [5].

Another essential issue in diagnosing skin diseases is vague symptoms. Examining skin diseases becomes complex and challenging. Since Zadeh introduced it in 1965, fuzzy logic has been successfully applied for various applications, mainly in control. This 'fuzzy' boom has generated strong interest from researchers in developing new fuzzy-based technology for various applications. Prior to the theory of fuzzy logic, we know as crisp logic, which has a value of true

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and false explicitly [9]. Otherwise, Fuzzy logic is logic that has a value of vagueness or ambiguity (fuzziness) between true and false. In fuzzy logic theory, a value could be true and false simultaneously. People unfamiliar with fuzzy logic would have thought that fuzzy logic is very complicated and unpleasant. However, once people know it, they will be interested and newcomers to studying fuzzy logic [10].

This research aims to develop a novel fuzzy-based medical expert system for diagnosing skin diseases. Based on the imprecise patient's symptoms, the system can produce output depending on the fuzzy inference system's situation. This fuzzy logic-powered system would be an application tool that makes it easier to figure out what might be going on with your skin. By answering your symptoms, the system gives the skin disease diagnosis with a certain confidence level. The AI model analyzes this information and draws from its knowledge to provide you with possible matching diseases. Moreover, it will also show you the severity level and give answers to common questions. The tool is not intended to provide a diagnosis nor be a substitute for medical doctors.

In this study, we used Matlab to develop the system because it is easy to run, performs information retrieval, and assists in calculations. The fuzzy approach is adopted to calculate drug compatibility and types' value. Paramedics and doctors can also use the system to recommend medicine. Numerical experiments using 100 (one hundred) datasets have been conducted to evaluate the effectiveness of the systems. The results are compared with those of the expected results by experts (doctors). It is shown that the system is effective and helps doctors diagnose skin diseases.

We organize this paper into five sections. The literature review of the medical expert system is given in the next section. The third presents a straightforward design of the proposed approach. The numerical experiments and the comparative results are described in the fourth section. Finally, conclusions are drawn in the last session.

II. Literature Review

Several researchers have reported the uses of various Artificial Approaches for medical problems. In the following Table I, several recent AI approaches for various skin diseases are presented.

Based on the above information, it can be seen that most of the previous approaches used a deterministic process. In this research, a novel technique called the fuzzy expert system is developed to diagnose skin disease.

TABLE I. Previous AI Approaches for Skin Diseases

Id	Authors	Title	Algorithm
1	Hameed et al., 2020 [11]	Multi-Class Multi-Level Classification Algorithm for Skin Lesions Classification using Machine Learning Techniques	Machine Learning
2	Dhiaksa, 2020 [12]	Expert System for Diagnosing Skin Diseases Using the Forward Chaining Method	Forward Chaining
3	Lumini et al., 2020 [13]	A fair comparison of skin detection approaches on publicly available datasets	Convolutional Neural Network (CNN)
4	Yogi & Udjaja, 2018 [14]	Android Application for Detection Of Skin Cancer Using Expert System	Backward Chaining
5	Ma et al., 2017 [15]	Effective Features to Classify Skin Lesions in Dermoscopic images	Support Vector Machine
6	(Waruwu & Simangunsong, 2014 [5]	Application of Certainty Factor Method for Diagnosis Expert System Skin Diseases In Humans	Certainty Factor
7	Sun et al. [16]	A Benchmark for Automatic Visual Classification of Clinical Skin Disease Images	Convo- Lutional Neural Networks (CNN)
8	Alkolifi Alenezi, 2019 [17]	A Method of Skin Disease Detection Using Image Processing and Machine Learning	Machine Learning
9	Rinivasu et al., 2021 [18]	Classification of Skin Disease Using Deep Learning Neural Networks with MobileNet V2 and LSTM	Deep Learning Neural Networks
10	Srinivasu et al., 2021 [18]	Classification of Skin Disease using Ensemble Data Mining Techniques	Ensemble Data Mining
11	Martiano et al.,2019 [19]	Detection of Potential Skin Cancer Lentigo Maligna Melanoma and Nodular Melanoma with Expert System Using Variable-Centered Intelligent Rule System (VCIRS) Method	Variable-Centered Intelligent Rule System (VCIRS)
12	Pour & Seker, 2019 [20]	Transform domain representation-driven convolutional neural networks for skin lesion segmentation	convolutional neural networks
13	This research	Implementation of Fuzzy Expert System on Skin Diseases	Fuzzy

III. Materials and Methods

This research has several stages of designing an expert system for skin diseases. The process starts with collecting literature studies. Then the second stage is identifying system requirements. The third stage is developing knowledge-based and compiling a membership function to determine the maximum and minimum value of the weight value of each symptom. Next is the development of the system stage. Finally, experiments are done to evaluate the functional system and compare the results with those of experts. The design of the system process in this study is illustrated in the following Fig. 1.

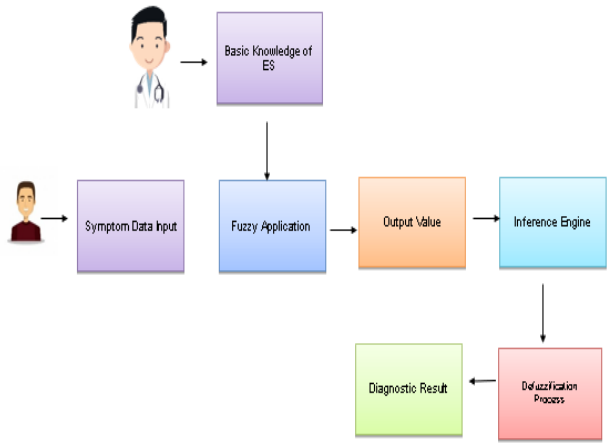


Fig. 1. The design of the system.

A. Symptom and Disease Datasets

This study used 10 (ten) types of skin diseases and 23 (twenty-three) symptoms. The data are given by an expert who is a skin doctor. The types of conditions and the symptoms are presented in Tables II and III. Each sign of the disease will have a weight value. We summarize the weight symptom value of the disease in Table IV.

TABLE II. Skin Disease Data

Code	Skin Disease
D01	Crustose Impetigo
D02	Bullous Impetigo
D03	Neurodermatitis
D04	Cellulitis
D05	Scabies
D06	Candida Cutis
D07	Herpes Zoster
D08	Furuncle
D09	Tinea Versicolor
D10	Tinea Cruris

TABLE III. Skin Disease Symptom Data

S1	S2	S3
Spots appear in the groin area and anus	A rash appears on the facial area	A red rash in the groin area, underarm skin, and breast folds
S4	**S5**	**S6**
Swelling of the skin in the lymph area	Reddish skin blisters on the lower legs, arms, abdomen, or face	Red spots or whitish lesions
S7	**S8**	**S9**
Itchy patches on the wrists, arms, ankles to the genitals or anus	There is a lump	There is a bull that can make wounds
S10	**S11**	**S12**
Have sores that itch	There are red spots	Feeling itchy
S13	**S14**	**S15**
Very itchy, like burning	At night itchy	Feel itchy when sweating
S16	**S17**	**S18**
On one side of the body appears blisters	There is a brownish-yellow scab around the wound as a result of an irritated wound	Skin feels dry, thick, and scaly
S19	**S20**	**S21**
Smooth scaly skin	Fever	Headache or Feeling Dizzy
S22	**S23**	
Pain in the spine	Rash spots on the surface of the skin	

TABLE IV. Symptom Weight Values for the Diseases

Diseases	Symptoms	Weight Value (Percent)
Crustose Impetigo (D01)	S02	30%
	S04	10%
	S17	50%
	S20	10%
Bullous Impetigo (D02)	S02	20%
	S04	10%
	S05	25%
	S09	25%
	S16	10%
	S20	10%
Neurodermatitis (D03)	S10	20%
	S12	20%
	S14	30%
	S15	20%
	S18	10%
Cellulitis (D04)	S01	12,50%
	S02	12,50%
	S03	12,50%
	S04	12,50%
	S05	12,50%
	S09	12,50%
	S16	12,50%
	S20	12,50%
Scabies (D05)	S01	10%
	S03	10%
	S04	5%
	S07	15%

Diseases	Symptoms	Weight Value (Percent)
	S10	10%
	S11	10%
	S12	10%
	S14	15%
	S20	5%
	S24	10%
Candida Cutis (D06)	S01	20%
	S02	10%
	S03	20%
	S10	10%
	S11	20%
	S12	20%
Herpes Zoster (D07)	S01	5%
	S02	7,5%
	S03	5%
	S04	10%
	S05	7,5%
	S09	5%
	S13	15%
	S16	15%
	S20	10%
	S21	10%
	S23	10%
Furuncle (D08)	S04	20%
	S08	70%
	S20	10%
Tinea Versicolor (D09)	S02	5%
	S03	15%
	S06	5%
	S12	35%
	S15	5%
	S19	35%
Tinea Cruris (D10)	S01	25%
	S03	25%
	S10	10%
	S12	20%
	S15	20%

B. Fuzzy Rules

To map the inputs to output, we define several fuzzy rules based on the information given by experts. The fuzzy rules are usually in the form of IF-THEN, made by experts or doctors. The defuzzification process converts the fuzzy output from the system inference engine into a definite value to determine the diagnostic results) [9]. An overview of tree- structure of the expert system on skin diseases is given in the following Fig. 2.

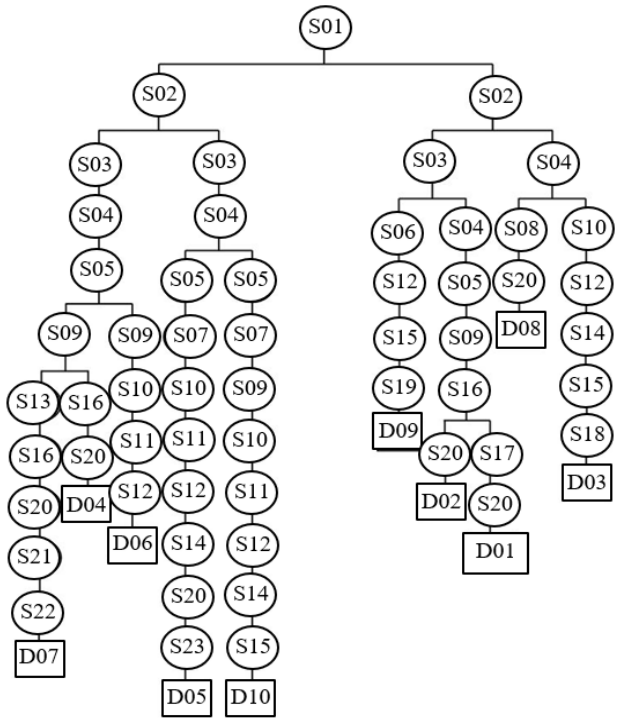


Fig. 2. The tree structure of the system.

C. Fuzzy Logic Controller

The concept of fuzzy logic was then successfully applied to a controller by Zadeh. Recently, it has been used for many applications in our daily life. Thousands of electronic products in the market have adopted the concept of fuzzy logic, ranging from washing machines to high-speed trains. It has been reported that the advantages of fuzzy logic in the sense of performance, simplicity, low cost, and productivity [21]

There are three steps passed before obtaining the crisp value. The processes of fuzzy are as follows:

- Fuzzification is the process of transforming crisp input values into linguistic values, which are usually presented in the form of fuzzy associations with a membership function respectively.
- An interference System is a reference for explaining the relationship between the variables of input and output variables that are processed and the resulting shaped fuzzy. To illustrate the relationship between inputs and outputs, the "IF-THEN" is used.
- Defuzzification is a process of changing the form of fuzzy variables into the data bound (crisp) that can be transmitted to the control equipment.

The step-by-step fuzzy logic process is shown in Fig. 3. The raw input is crisp. The Fuzzification process produces the fuzzy value, which is then calculated by the membership function. Later, the defuzzification process converts it back to the crisp value, as shown in Fig. 3.

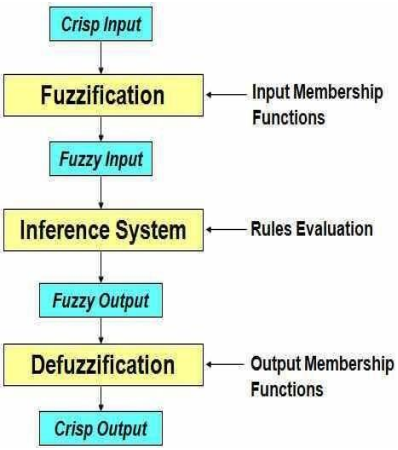
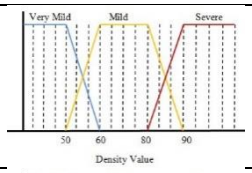
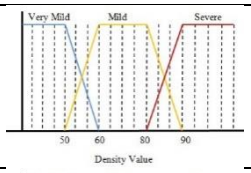
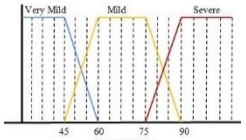
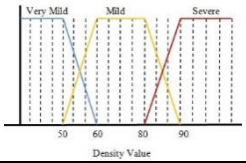
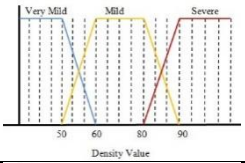
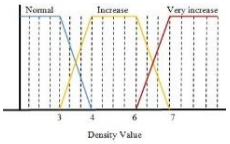
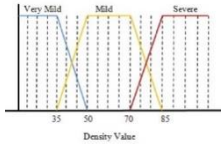
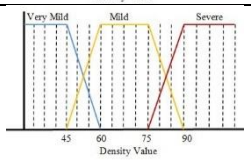
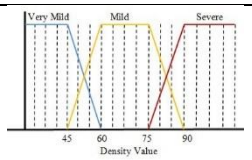
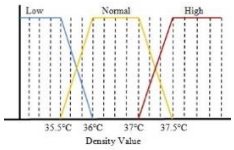
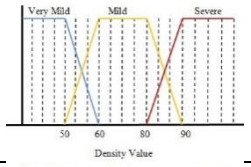
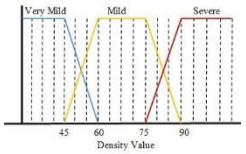
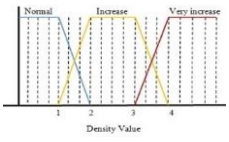
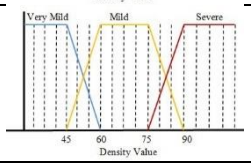
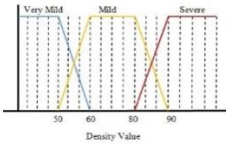
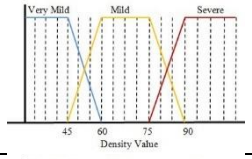
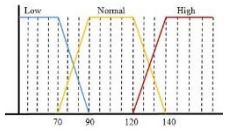
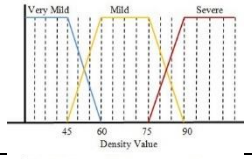
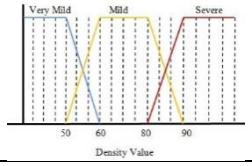
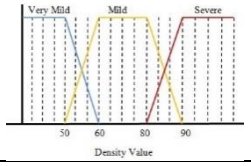
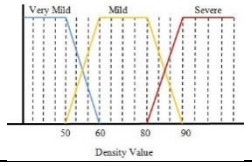


Fig. 3. Step-by-step fuzzy logic approach.

1) Fuzzy membership function: Unlike traditional Crisp Logic, such as Binary Logic, where variables may only take on true and false values represented by 1 or 0, the variables in fuzzy logic may have a truth value in the range of 0 and 1 [22]. The value called membership value explains the degree of truth. Here, the fuzzification process transforms the symptom density value into a linguistic variable using a membership function. The function represents the membership degree of the input variable, denoted by the symbol μ (x), in the interval between 0 on the information given by experts. For this research, we used fuzzy symptoms membership functions, as shown in Table V. We also used criteria and density values for each symptom criterion in this research. The data was obtained from a dermatologist with a practice permit, as shown in Table VI.

TABLE V. MEMBERSHIP FUNCTION OF THE SYMPTOMS

Symptom		Symptom		Symptom	
S01		S09		S17	
S02		S10		S18	
S03		S11		S19	
S04		S12		S20	
S05		S13		S21	
S06		S14		S22	
S07		S15		S23	

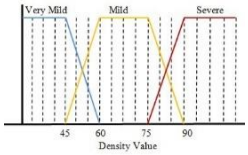
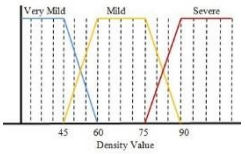
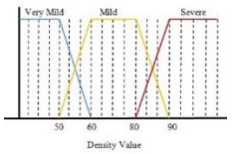
S08		S16		S24	

TABLE VI. THE DENSITY VALUES OF THE SYMPTOMS

Code	Symptom	Criteria	Density Value
S01	Spots appear in the groin and anus area	- Pink spots without freckles	40
		- Pink spots with freckles	55
		- Bright red spots with freckles	70
		- Bright red patches with flaky or scaly spots	82
		- Dark red or black patches with flaky or scaly spots	90
S02	A rash appears on the facial area	- A red rash resembling a wound with nodules filled with clear fluid	78
		- A brownish, crusty rash with nodules filled with clear fluid	85
S03	A red rash in the groin area, underarm skin, and breast folds	- Red rash and red, cracked, dry plaques	75
		- A red rash with pus-filled bumps and red, well-defined plaques	85
S04	Swelling of the skin in the lymph area	- Significant red swelling that feels rough and painful	74
		- Significant red swelling that feels rough and contains pus or blood	88
S05	Reddish skin blisters on the lower legs, arms, abdomen, or face	- The pink skin blisters feel swollen and warm and look shiny	65
		- Red skin blisters that are swollen and inflamed (painful)	78
		- Red skin blisters with bubbles filled with fluid or pus	85
S06	There are red spots or whitish lesions	- Pink lesions	63
		- Red lesions	78
		- Whitish patches	85
S07	There are itchy patches on the wrists, arms, ankles, genitals, or anus	- Itchy patches with red or darker than the surrounding skin	65
		- Itchy patches feel rough and scaly and thick	77
		- Itchy patches with open sores that can lead to infection	85
S08	There is a lump	- The bumps are red and not hard	50
		- Red bumps that are inflamed and hard-filled with pus	74
		- White bumps like a pile of pus, and around the lump is red	85
S09	There is a bull that can make wounds	- There are several bullies in certain body parts	65
		- There are many red bullies like hives that feel itchy	85
S10	Have sores that itch	- The wound is starting to itch	65
		- Burns that feel hot and itchy	78
		- Burns that feel hot, very itchy, and scaly	85
S11	There are red spots	- There are some small red nodules	60
		- There are rashes and red skin blisters filled with clear fluid	77
		- There are nodules and red, inflamed skin blisters filled with clear fluid	85
S12-	Feeling itchy	- itchy	60
		- a bit itchy	78
		- very itchy	85
S13	Very itchy, like burning	- itchy like burning	60
		- a bit itchy, like burning	78
		- very itchy, like burning	85

Code	Symptom	Criteria		Density Value
S14	At night itchy	-	itchy at night	60
		-	a bit itchy at night	78
		-	very itchy at night	85
S15	Feel itchy when sweating	-	itchy when sweating	60
		-	a bit when sweating	78
		-	very itchy when sweating	85
S16	On one side of the body appears blisters	-	Red blisters that start to become inflamed and itchy	70
		-	Red blisters are painful, itchy, and filled with fluid	83
		-	Red blisters that fill with fluid and break into crusts	88
S17	There is a brownish-yellow scab around the wound as a result of an irritated wound	-	Yes	85
		-	No	0
S18	Skin feels dry, thick, and scaly	-	Dry skin	60
		-	Skin feels dry and flaky	78
		-	Skin feels dry, thickened, and scaly	85
S19	Smooth scaly skin	-	Yes	85
		-	No	0
S20	Fever	-	Low	35 C - 36 C
		-	Normal	36,1 C - 37,5 C
		-	High	37,6 C - 38 C
S21	Headache or Feeling Dizzy	-	Feeling sick at one point	65
		-	Like spinning	78
		-	Feels floating or head feels heavy	85
S22	Pain in the spine	-	Feel pain	65
		-	Feel a bit of spinal pain	78
		-	Feel very of spinal pain	85
S23	Rash spots on the surface of the skin	-	Rash of pink spots	65
		-	A rash of bright red spots that start to become inflamed	78
		-	A rash of red, inflamed spots that feels rough	88

IV. The Numerical Experiments and Results

We develop a fuzzy-based expert system for diagnosing kidney diseases using MATLAB R2020a and run on PC Processor Intel® Core™ i3-7020U. For the experiments, we used 100 (one hundred) test problems from the Abdoel Moeloek National Hospital in Lampung. We compared the results of the system with those given by the Doctor.

This system first displays questions from each symptom according to the closest symptom. After selecting the related symptom, the system will show a selection of symptom criteria. Finally, the diagnostic results will be displayed. After choosing the symptoms, the system will present the results as illustrated in Fig. 4.

The system's output will be the diagnostic results and its confidence level. We compared the results with those given by the expert (dermatologist) and the system in Table VII. These results show that the system succeeds in diagnosing the patient's disease for all tests. It can analyze the conditions precisely the same as given by experts.

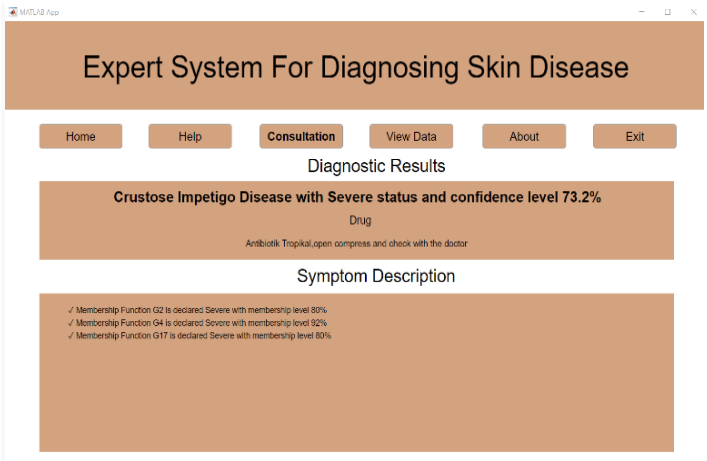


Fig. 4. User Interface of the system.

TABLE VII. COMPARATIVE RESULTS BETWEEN EXPERTS AND SYSTEM

		Predicted by the System									
	Type of Disease	**D01**	**D02**	**D03**	**D04**	**D05**	**D06**	**D07**	**D08**	**D09**	**D10**
Actual by the expert	D01	5	0	0	0	0	0	0	0	0	0
	D02	0	12	0	0	0	0	0	0	0	0
	D03	0	0	8	0	0	0	0	0	0	0
	D04	0	0	0	13	0	0	0	0	0	0
	D05	0	0	0	0	13	0	0	0	0	0
	D06	0	0	0	0	0	13	0	0	0	0
	D07	0	0	0	0	0	0	13	0	0	0
	D08	0	0	0	0	0	0	0	2	0	0
	D09	0	0	0	0	0	0	0	0	13	0
	D10	0	0	0	0	0	0	0	0	0	8

TABLE VIII. NUMERICAL EXPERIMENT RESULTS

				System		
Disease	**Problem**		**Status**	**Very Mild**	**Mild**	**Severe**
D01	5		**Very Mild**	0	0	0
		Expert	**Mild**	0	1	0
			Severe	0	0	4
D02	12		**Very Mild**	0	0	0
			Mild	0	6	0
			Severe	0	0	6
D03	8		**Very Mild**	0	0	0
			Mild	0	2	0
			Severe	0	1	5
D04	13		**Very Mild**	0	0	0
			Mild	0	6	0
			Severe	0	0	7
D05	13		**Very Mild**	0	0	0
			Mild	0	6	0
			Severe	0	0	7
D06	13		**Very Mild**	0	0	0
			Mild	0	5	0
			Severe	0	0	8
D07	13		**Very Mild**	0	0	0
			Mild	0	6	0
			Severe	0	0	7
D08	2		**Very Mild**	0	0	0
			Mild	0	0	0
			Severe	0	0	2
D09	13		**Very Mild**	0	0	0
			Mild	1	4	1
			Severe	0	2	5
D10	8		**Very Mild**	0	0	0
			Mild	0	3	0
			Severe	0	0	5

Next, for each test problem, the system also provides the severity level for each patient. Table VIII shows the comparative results of experts and the developed system on the disease severity for the patients. Based on these results, we calculate the system's accuracy in determining the patients' disease severity, as shown in Fig. 5.

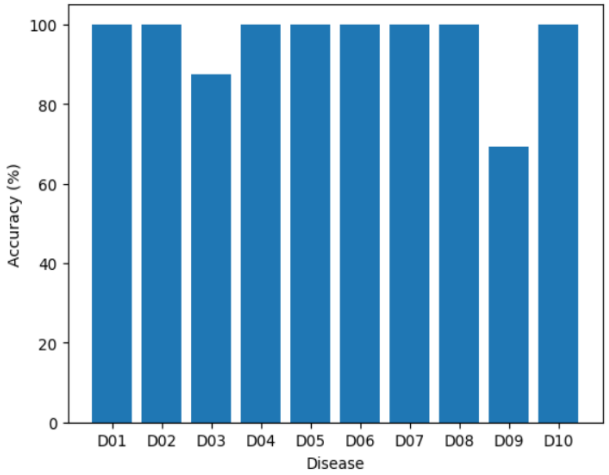


Fig. 5. Expert diagnostic test chart and system.

The above results show that the system's accuracy in determining the severity level of the patient's disease is 95.6%. It shows that this system is effective in diagnosing skin disease. Thus, the system is very beneficial to support doctors in assessing skin diseases.

V. Conclusion

The diagnosis of skin diseases is a difficult task. There is always some possibility of misdiagnosis that leads to miss treatment. This research presents a fuzzy expert system to examine skin diseases based on patient symptoms. The system gives information about the type of disease with confidence based on the existing symptoms and how to handle them. The system's output will be the type of disease and its attributes, namely very mild, mild, and severe. We had several experiments to evaluate the system's performance using 100 test problems and compared the results with those given by the expert (dermatologist). The result shows that the system succeeds in all of the tests. Thus, this system is very beneficial to supporting doctors in the assessment of skin diseases.

Acknowledgments

The authors express their deepest gratitude for using the facilities of the Basic Computing Laboratory, Department of Computer Science, and the University of Lampung to support this research and for the willingness of dr. Hendra Tarigan Sibero, Sp.KK, M. Kes. who has contributed his practical knowledge to this skin disease expert system. A "Fundamental" research Grant supported this research.

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