Implementation of Fuzzy Inference System in Children Skin Disease Diagnosis Application

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Abstract — **This paper discussed the use of fuzzy inference system in children's skin disease diagnose application. The selected diseases to be diagnosed by the application are measles, German measles and chicken pox. These diseases were selected due to their similarities in pattern of infection and symptoms such as rash and fever. The built fuzzy inference system has input variables that represent the symptoms that may appear in each disease. The used fuzzy rules generated from experts' knowledge and literature. Additional features to modify the inference system also included in the application. The application diagnosed diseases from 19 of 25 data represent patients' condition correctly.**

Keywords—children's skin disease; symptom; fuzzy logic; inference system; application

I. Introduction

Expert systems have been used widely in many fields, including medicine. In medicine field, many expert systems have been designed to help experts in analyzing patient's condition. The first medical expert system, MYCIN has inspired the development of other medical expert system such as INTERNIST and EMERGE [1]. Most developed expert systems use forward chaining and decision tree method to identify the disease or patient's condition.

Any disease suffered by patient should be known clearly so it can be treated correctly, including skin diseases. There are various kinds of skin disease which some of them share similar symptoms to each other. At the time of diagnosis, not all perceived symptoms can be seen clearly from the patient [2]. The concept of fuzzy logic can be used in dealing with this uncertainty during diagnosis. The concept is used in logic rules compiled based on experts' knowledge.

The number of publication about fuzzy logic application in medicine field has increased since 2000 [3]. Fuzzy logic concept has been used in an inference system for sepsis diagnosis [4]. Fuzzy relation concept also has been used to diagnose measles and chickenpox [5]. Both gave good result and a conclusion that fuzzy logic has a potential to be used in the diagnosis of diseases. It also inspired the development of fuzzy inference system for skin disease diagnosis.

II. Basic Theories

A. Children Skin Disease

The chosen diseases that are going to be diagnosed by the application are measles, German measles and chickenpox. These diseases are caused by virus infection, can be prevented by vaccines and share similar symptoms. This section describes details of the diseases further.

1. Measles

Measles (*rubeola*) is a disease caused by viruses transmitted by aerosolized respiratory droplets and by direct contact [6]. The infection stage of measles begins with the incubation period in 10 – 14 days. During this period, the symptoms have not been seen.

Towards the end of the incubation period, patients develop prodromal symptoms of high fever, cough, *coryza* (runny nose) and conjunctivitis [6]. In patients who have not been immunized, bluish white spot inside mouth area can be found. This spot often called as Koplik's spot. The typical rash first appears after another 3 - 4 days, often accompanied by higher fever. The rashes are initially found on the face and behind the ears and then spread throughout the body as shown in figure 1. The spread of rashes is accompanied by fever down and disappearance of prodromal symptoms. The spread rashes generally turn brown and then disappear. Complications of measles may include diarrhea, ear infections, bronchitis, pneumonia, and encephalitis.

Fig. 1. Illustration of rash on measles [7]

Fig. 2. Spesific rash of chickenpox

2. German measles

German measles (*rubella*) is caused by a virus different from measles virus and has symptoms which are not as severe as measles. In children, German measles affects the skin and lymph nodes [8]. The symptoms appear for 2 – 3 days after the second week since the beginning of the viral infection [9]. The symptoms sometime feel lighter than the measles. The infection usually begins with a mild fever, malaise and mild conjunctivitis. Symptoms such as headache, runny nose and loss of appetite may also be found. Those symptoms appear before the appearance of rashes that spread from the face throughout the body. The rash characteristic is similar to the rash of measles as shown in figure 1. This disease is characterized by joint pain and lymph nodes that make the neck and ear swollen since the infection began.

3. Chickenpox

Chickenpox [10] is an acute infectious disease caused by varicella zoster virus (VZV). The appearance of the rashes of this disease can be accompanied by flu-like symptoms. The non-specific symptoms for this disease are mild fever, headache, malaise, sore throat, diarrhea and loss of appetite. These symptoms appear within a short time. The suffered fever may be higher when complication occurs.

The rash of this disease is more recognizable than any other disease as shown in figure 2. The rash begins as multiple small red bumps that look like pimples or insect bites, usually less than a quarter of an inch wide [11]. They appear in crops over 2 to 4 days and develop into thin-walled blisters filled with fluid. The blister walls break, leaving open sores, which finally crust over to become dry, brown scabs. The red bumps, blister and crust can appear simultaneously and continues to appear in a few days. The rashes spread from the face to the entire body and can be concentrated on the neck. Specific rash of this disease appears only if the patient has not been vaccinated. After being vaccinated, the disease can reappear with a non-specific rash. That's when the symptoms are difficult to distinguish from the symptoms of measles.

B. Fuzzy Logic

Fuzzy logic concept was introduced by Lotfi A. Zadeh through his publication in 1965 [12]. Fuzzy logic is used to deal with uncertainty and inaccurate problems. The concept of fuzzy logic was developed based on uncertainty and interpretation of natural language in the real world.

In fuzzy logic, there are fuzzy variables which have some linguistic values [13]. The linguistic value often named as an adjective which describe qualitative value of the variable itself. Quantitative value of the linguistic value is called membership value which determined by a membership function. The membership function can have all values between 0 and 1 [13]. The closer the characteristics of a variable to a linguistic value, the higher the value of its membership function of the linguistic value.

The operations known in crisp sets such as union, intersection, complement and difference are also known in fuzzy sets. Predicates in fuzzy logic have form

V is F

where V and F represent a fuzzy variable and a linguistic value respectively. The predicate is used in a fuzzy rule with form

If A then B

where A and B represent antecedent and consequent block respectively that may contain more than one predicate. Both block may contain AND, OR and NOT operator. This form of fuzzy rule is used generally in a fuzzy inference system.

C. Fuzzy Inference System

A fuzzy inference system contains one or more fuzzy rules. Generally, the steps performed by a fuzzy inference system are [4]:

1. Fuzzification or the step of determining the degree of membership of each predicate from each input value [13].
2. Determination of membership value of antecedent part if there are fuzzy logic operations involved.
3. Implication or step of calculating the membership values of the consequent part of each rule based on its membership value of its antecedent. This method of implication is called Mamdani method.
4. Aggregation which is done if there is more than one fuzzy rule is evaluated. At this step, OR operation is done on all the outputs of the implication step. The stage is also part of the Mamdani method.
5. Defuzzification or the step of evaluating the crisp value from the aggregated area. The most common used method in this step is centroid method. This method is equivalent with calculating the center of gravity of the aggregation result. The computational scheme is written as [13]

$$z^* = \frac{\int z.\mu_c(z)dz}{\int \mu_c(z)} \qquad (2.1)$$

III. Analysis

A. Diagnosing Skin Disease

The three skin diseases diagnosed by the application are characterized by rash and fever suffered by the patient. These diseases can be distinguished according to the pattern of its infection and combination of additional symptoms that also indicate the three diseases. For instance, in measles, the suffered fever is higher as the severity of infection increase. In German measles and chickenpox, the fever is not as heavy as in measles. Some typical symptoms can directly lead to the diagnosis of specific diseases. One of the typical symptoms is Koplik's spot in the mouth that indicate measles. Table I shows the additional symptoms of the three diseases based on the description in section II.A.

B. Analysis of the Fuzzy Inference System

In the three skin diseases, body temperature which can describe the suffered fever and how rash spread on the body can be represented as fuzzy variables with linguistic values mild, normal and heavy. The value of variable represent rash distribution is determined by the standard below. The standard has been confirmed by the expert.

$$rash = \begin{cases} 0-3 \quad , & \text{if rash found in face} \\ 3-5 \quad , & \text{if rash found in face and neck} \\ 5-7 \quad , & \text{if rash also jika found in arm and leg} \\ 7-10 \quad , & \text{if rash also found in the other part of the body} \end{cases} \tag{3.1}$$

Each additional symptom mentioned at table I can be the input during diagnosis. However these symptoms can't be represented as a single fuzzy variable like the two previous symptoms. The number of specific symptoms found can be calculated to determine the proximity of the characteristics of the disease to the diagnosis results and expressed as other fuzzy variables with linguistic values little and many. The calculations of the value of these variables are based on the amount of weight of the symptoms given in Table II.

TABLE I. ADDITIONAL SYMPTOMS OF THE THREE DISEASES

Symptom	**Measles**	**German Measles**	**Chickenpox**
Cough	Yes	No	Yes
Runny nose	Yes	Yes	Yes
Sore throat	Yes	No	Yes
Conjunctivitis	Yes	Yes	No
Koplik's spot	Yes	No	No
Diarhea	Yes	No	Yes
Headache	No	Yes	Yes
Swollen neck or ear	No	Yes	No
Loss of appetite	No	No	Yes
Malaise	No	Yes	Yes
Pimples/crust skin	No	No	Yes
Joint pain	No	Yes	No

TABLE II. THE VALUE OF WEIGHT OF EACH SYMPTOM TO EACH DISEASE

Symptom	**Measles**	**German Measles**	**Chickenpox**
Cough	0.5	0	0.5
Runny nose	0.5	1	0.5
Sore throat	0.5	0	0.5
Conjunctivitis	0.5	0.5	0
Koplik's spot	1	0	0
Diarhea	3	0	0.5
Headache	0	0.5	0.5
Swollen neck or ear	0	2	0
Loss of appetite	0	0	2
Malaise	0	2	0.5
Pimples/crust skin	0	0	4
Joint pain	0	2	0

The diagnosis result is the most possible suffered disease. The severity of the diseases can be represented as output fuzzy variables with linguistic values mild, normal and heavy. The most possible suffered disease is the disease with the largest defuzzification result.

Therefore in the built fuzzy inference system, there are 5 input variables and 3 output variables. The input variables are fever, rash and three variables represent the number of symptoms match the diagnosed diseases. These variables have same membership functions. Three output variables also represent the severity of the diseases in the patient's body. These variables also have same membership functions with each other. The membership functions of each variable are shown in Figure 3.

There are 21 fuzzy rules used and were compiled based on literature and experts' experience. The rules consist of 8, 6 and 7 rules to diagnose measles, German measles and chickenpox respectively. Those fuzzy rules are

1. IF Fever is Safe AND SpMeasles is Few THEN Measles is Safe
2. IF Fever is Safe AND Rash is Normal AND SpMeasles is Few THEN Measles is Normal
3. IF Fever is Safe AND Rash is Normal AND SpMeasles is Many THEN Measles is Normal
4. IF Fever is Safe AND Rash is Severe AND SpMeasles is Many THEN Measles is Severe
5. IF Fever is Mild AND Rash is Mild AND SpMeasles is Few THEN Measles is Mild
6. IF Fever is Mild AND Rash is Normal AND SpMeasles is Few THEN Measles is Normal
7. IF Fever is High AND Rash is Mild AND SpMeasles is Few THEN Measles is Normal
8. IF Fever is High AND Rash is Normal AND SpMeasles is Few THEN Measles is Normal
9. IF Fever is Safe AND SpRubella is Few THEN Rubella is Safe
10. IF Fever is Safe AND Rash is Mild AND SpRubella is Many THEN Rubella is Mild
11. IF Fever is Safe AND Rash is Normal AND SpRubella is Few THEN Rubella is Mild
12. IF Fever is Safe AND Rash is Severe AND SpRubella is Few THEN Rubella is Severe
13. IF Fever is Mild AND Rash is Mild AND SpRubella is Few THEN Rubella is Mild
14. IF Fever is Mild AND Rash is Normal AND SpRubella is Few THEN Rubella is Normal
15. IF Fever is Safe AND SpChicPox is Few THEN ChicPox is Safe
16. IF Fever is Safe AND Rash is Normal AND SpChicPox is Few THEN ChicPox is Normal

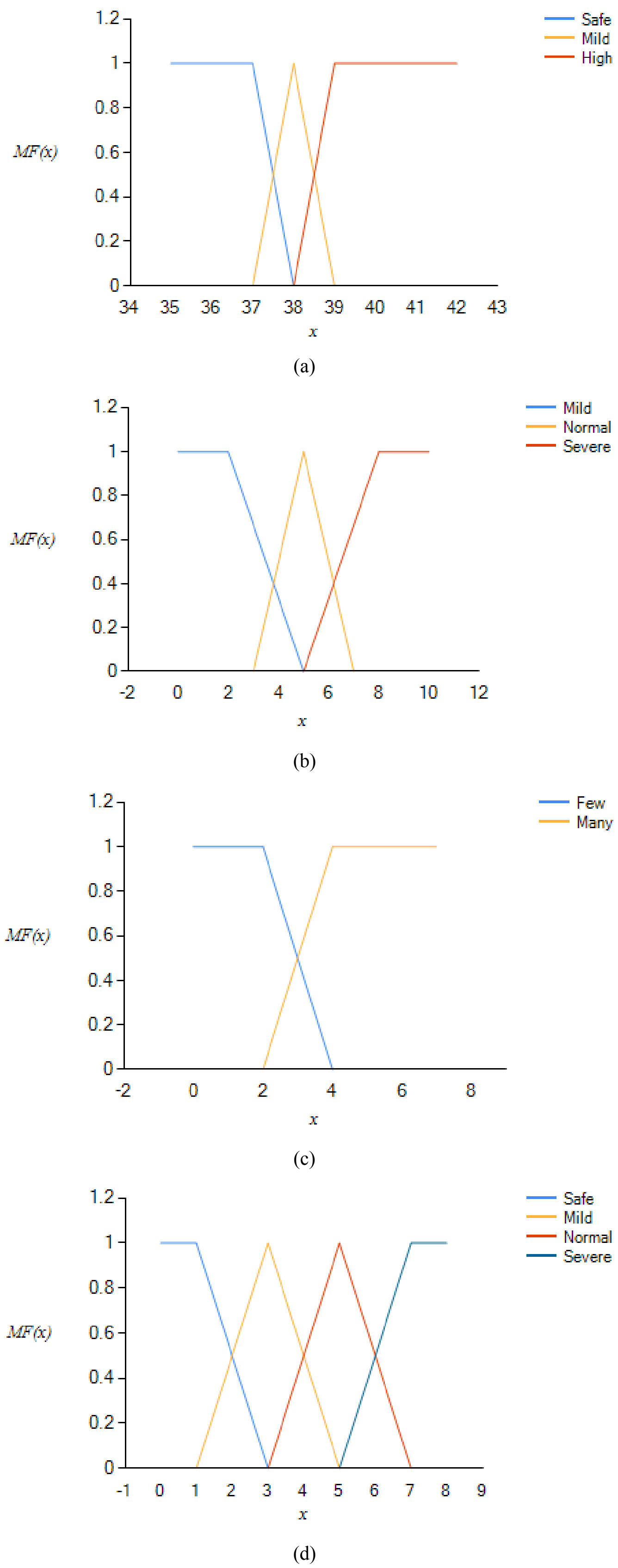

Fig. 3. Membership function for variables: (a) fever, (b) rash, (c) appearance of symptoms in each disease, (d) output disease

17. IF Fever is Safe AND Rash is Normal AND SpChicPox is Many THEN ChicPox is Severe
18. IF Rash is Severe AND SpChicPox is Many THEN ChicPox is Severe
19. IF Fever is Mild AND Rash is Mild AND SpChicPox is Few THEN ChicPox is Mild
20. IF Fever is Mild AND Rash is Normal AND SpChicPox is Many THEN ChicPox is Normal
21. IF Rash is Severe AND SpChicPox is Few THEN ChicPox is Severe

C. Application Requirement

The application is used for diagnose the skin disease in children's body. The diagnosis process utilizes fuzzy inference system described on section III.B. The configuration of the inference system also can be saved and loaded in an external file.

Within the application, the user, with the expert also can add, modify and delete fuzzy rules or symptoms known by the application. The used fuzzy variables and their membership functions can be modified too. This configuration features can be done if there is new knowledge from the expert. The user also can see the detail of components of fuzzy inference system.

IV. Implementation

The application was implemented with C# programming language. The interface of the main feature is shown in figure 4. Configuration features mentioned in section III.C also implemented so that the user can modify the inference system. The inference system was implemented with classes described in table III. `Symptom` class that used to represent a symptom and `Diagnoser` class that contains the inference system and list of known symptoms were also implemented.

TABLE III. Class Details of the Inference System

Class	Description
`FIS`	The class which contains list of fuzzy variables, fuzzy rules and implication results. This class performs implication and aggregation step.
`FuzzyVar`	The class represents a fuzzy variable and contains list of its membership functions, initial crisp input and name of the variable.
`ImpArea`	The class represents an area resulted in implication step which contains resulted fuzzy variables, its membership function and fuzzy operation result of the antecedent.
`MemFunction`	Abstract class of a membership function. This class performs fuzzification.
`Proposition`	The class represents a fuzzy predicate and contains variable and membership function.
`Rule`	The class represents a fuzzy rule which contains list of antecedents and consequents. This class performs fuzzy logic operation.

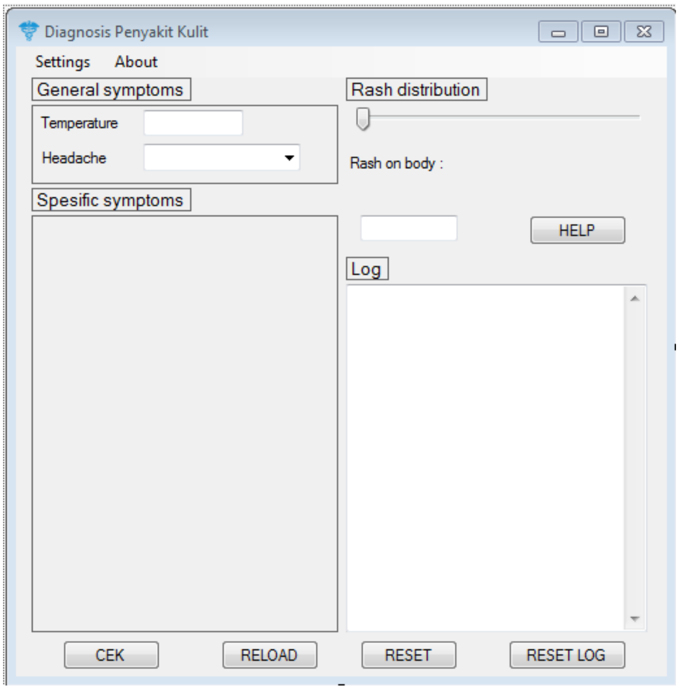

Fig. 4. Interface of the application

The external file that contains configuration script of the application was also made. The file contains list of symptoms also its weight relative to each disease, specification of the fuzzy variables and set of the fuzzy rules.

V. Result and Discussion

There are two test scenarios done. The first test is to determine whether the inference system can give the correct defuzzification result. In this test, the equivalent inference system was also built with Fuzzy Logic Toolbox in Matlab. Same set of crisp values was given to both inference system and both gave same defuzzification result. Therefore, the build inference system has been implemented correctly.

The second test is to determine whether the diagnosis result of the application is equal with expert's diagnosis result. In this test, 25 patients' data are used. The patients are considered to suffer one of the three diseases. The patient's data contains information about body temperature, the headache suffered and other specific symptoms found in patient's body. The patients' data were compiled based on experts' experience and contain information about 9 measles patients, 7 German measles patients and 9 chickenpox patients. Number of German measles patients' data is the least because in reality this disease is less common. The test result for each patient's condition is shown in table IV.

According to table IV, application was able to give 19 of 25 correct diagnosis results. The hardest disease to diagnose is chickenpox. This result matches with the real condition where chickenpox and measles are difficult to distinguish if the patient has received chickenpox vaccine. In 4 of 25 conditions, measles and chickenpox patients were diagnosed incorrectly. This test also shows the accuracy of fuzzy rules compiled with the experts.

TABLE IV. Comparison of Diagnosis Results by Expert and the Application

Patient	Expert diagnosis	Application diagnosis
1	Measles	Measles
2	Measles	Measles
3	Measles	Measles
4	Measles	Measles
5	Measles	Measles
6	Measles	Chickenpox
7	Measles	Measles
8	Measles	Measles
9	Measles	Measles
10	German measles	German measles
11	German measles	Chickenpox
12	German measles	All three diseases
13	German measles	German measles
14	German measles	German measles
15	German measles	German measles
16	German measles	German measles
17	Chickenpox	Chickenpox
18	Chickenpox	Chickenpox
19	Chickenpox	Chickenpox
20	Chickenpox	Chickenpox
21	Chickenpox	Measles, Chickenpox
22	Chickenpox	Chickenpox
23	Chickenpox	Measles, Chickenpox
24	Chickenpox	Chickenpox
25	Chickenpox	Measles, Chickenpox

From the result above, one can confirm that the most accurate rule set is rule for diagnosis of measles. This accuracy is because measles has the clearest infection pattern during observation of disease. Based on experts' knowledge and literature, symptoms of German measles and chickenpox are less regularly when observed. This implies the less accuracy of rules that are used in diagnosis of German measles and chickenpox. These rules can be tuned in order to improve the accuracy of the inference system. Beside of the rules, the used fuzzy variables also can be modified again to give a more accurate inference result. One of the modifications ways is to try other alternatives membership functions.

The accuracy of weight of each symptoms on the diseases affects the value of variables specify the number of typical symptoms of the diseases. Hence, the weighting also affects the inference result. It affects the diagnosis of patients with typical symptoms such as Koplik's spot, swelling neck or crust skin. At the previous test, 6 conditions where the patients have one of the typical symptoms were all diagnosed correctly.

VI. Conclusion

From the result above, the following conclusions can be derived:

1. The built fuzzy inference system has fuzzy variables represent body temperature, rash and number of symptoms of each disease on the patient.

2. The used fuzzy rules were compiled mostly based on experts' experience which are affects the accuracy of the system.
3. The application successfully diagnosed 19 of 25 right diseases during testing.
4. Weighting of each symptom and configuration of the used fuzzy variables can affects the accuracy of the inference system.

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