Early Detection of Hand, Foot, and Mouth Disease based on Palmprint using Certainty Factor as Expert System Method based on Android

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Abstract. Hand, foot, and mouth disease is an infectious disease caused by coxsackievirus. This virus lives in the digestive tract and spreads from person to person. Patients will get a rash on their hands, feet and mouth. An application that can do early detection for HFMD is needed, so patients can get the right references. The application is made for android based phone with expert system implementation. Method used for expert system is certainty factor using data that has been validated and is fully supported by doctors as experts. The output of this application is information on whether or not a patient is suffering from HFMD as well as recommendations to visit medical personnel for further examination. This paper is a result of testing the expert system to detect the HFMD. The accuracy, precision, and recall from this method is as high as 100%.

1. Introduction

In 2008 Singapore experienced the biggest Hand Foot Mouth Disease (HFMD) attack in which there were 29,686 cases and one fatal case occurred leading to death [1]. Symptoms are characterized by fever, mouth ulcers, and rashes with blisters on the hands, feet and buttocks [2]. HFMD itself is a disease that includes rapid spread, in addition it can also be aggravated by the level of poor sanitation and population density. This disease can cause potential extraordinary incident [3]. Therefore, it takes an expert system that is able to do early detection for HFMD with knowledge that comes directly from the experts. Method used for expert system is certainty factor (CF) using data that has been validated and is fully supported by doctors as experts.

Implementation of CF as expert system method to classify children disease based on web has been done by Luther A. Latumakulita [4]. Another work on CF as expert system method to classify HFMD and other children disease also has been done by Suryo Atmojo [5] using web as the base for the application.

In this work the author use CF as expert system method because it can provide accurate results obtained from calculations based on the weight of symptoms chosen by the user, able to provide answers to uncertain problems such as the problem of early diagnosis of disease, and with this method the expert describes the beliefs of an expert by giving appropriate weight weights with related expert knowledge [6]. In this work, the author already uses image processing to detect the rashes on the user’s palm. There are many works using image processing for medical purpose. One of it is A Survey on the Implementation of Image Enhancement by M. Aziz[7]. By referencing the other works, author is combining the image processing using SURF to detect the rashes and using Certainty Factor as expert system. Implementation of early detection for HFMD using CF as expert system method is made on android based smartphone as almost everyone nowadays use a smartphone with Android as operating system [8].
On the next section, the author will explain all the materials and method used for this work. This paper, will only discuss about the expert system that is used in the application.

2. Materials and Method

2.1. Certainty Factor
Expert systems must be able to work in uncertainty. Certainty Factor was introduced by Shortliffe Buchanan around 1970. The certainty factor is a clinical parameter value that can be used to show the measurement of belief that is given by MYCIN. Certainty Factor (CF) shows a measure of certainty about a fact or rule.

The usefulness of the Certainty Factor includes [9]:
1. Determine a measure of belief in the initial facts that will be given by each user,
2. Determine the measurement of beliefs until the conclusions or decisions obtained from the rules; experts determine this value to rules,
3. Determine the measurement of beliefs in the facts and results obtained throughout the reasoning process from the results of the execution of the rules,
4. Adjust the measurement of beliefs with facts or results obtained from different rules but produce the same conclusions.

Calculation formula to find certainty factors of single rule is as follows [10] :

$$CF[H,E] = MB[H,E] - MD[H,E]$$  

Given that :
- $CF[H,E]$ = The certainty factor in the $H$ hypothesis that is influenced by the fact $E$.
- $MB[H,E]$ = Measure of Belief, which is a measure of the increase in belief in the hypothesis $H$ that is influenced by the fact $E$.
- $MD[H,E]$ = Measure of Disbelief is an increase in the distrust of hypothesis $H$ influenced by fact $E$.

While calculation for rules of a single premise is defined as below :

$$CF[H,E]_{1} = CF[H] \times CF[E]$$  

Certainty factor for similary conclude rules :

$$CF_{combine} CF[H,E]_{1,2} = CF[H,E]_{1} + CF[H,E]_{2} - [CF[H,E]_{1} \times CF[H,E]_{2}]$$  

$$CF_{combine} CF[H,E]_{old,3} = CF[H,E]_{old} + CF[H,E]_{3} - [CF[H,E]_{old} \times CF[H,E]_{3}]$$  

2.2. Hand Foot, and Mouth Disease

Hand, Foot and Mouth Disease (HFMD) is an infectious disease that often occurs and affects infants and children. The characteristics of the symptoms are fever, sores in the mouth and a rash with patches on the hands, feet and buttocks [2].

HFMD is not the same disease as foot and mouth disease in animals, because it is caused by a different virus. Viruses from the enterovirus group are the cause of HFMD, especially the Coxsackie A16 (CA 16) and Enterovirus 71 (EV 71) viruses, whereas other serotypes that can cause this disease are CA 6 and CA 10 [2]. The dataset of this disease which has been validated by expert is defined below:
Table 1. Symptoms and Questions Dataset

| Symptoms                  | Questions                                           | Code |
|---------------------------|-----------------------------------------------------|------|
| Fever                     | Do you have a fever?                                | G1   |
| Fever less than three days| Is the fever happens less than three days?          | G2   |
| Rashes on Hand            | This symptom doesn’t have question because the result is from different system. | G3   |
| Rashes filled with liquid | Are the rashes on the palm filled with liquid?      | G4   |
| Rashes are red            | Are the rashes on the palm red?                    | G5   |
| Rashes also showed up on foot and mouth | Are the rashes also showed up on foot and mouth? | G6   |
| Rashes felt painful       | Are the rashes felt painful?                        | G7   |
| Rashes felt itchy         | Are the rashes felt itchy?                         | G8   |

Rules used for decision making by forward chaining is described below:
P1 = Indicated as HFMD
P2 = Not Indicated as HFMD
R1 : If G4 U G5 U G7 U G8 U G6  →  G3
R2 : If G3 U G2 U G6  →  G1
R3 : If G1 ∩ G3 ∩ G6 ∩ (G4 U G5)  →  P1
R4 : If G1 U G2 U G3 U G4 U G5 U G6 U G7 U G8  →  P2

2.3. Dataset for Certainty Factor

Input from users for the application is a yes or no answer that has its own weight for the certainty factor calculation process. The table below shows the weight values of each answer:

Table 2. Weight of User’s Answer

| Answer | Weight |
|--------|--------|
| Yes    | 1      |
| No     | 0      |

This system also receives input in the form of information from different systems that use image processing to determine whether or not the rashes are in the hand. If the rashes has been detected, the system will begin the certainty factor process. For the weight of each symptom can be seen in the table below:

Table 3. Weight of Questions

| Symptoms                  | Questions                                           | Weight |
|---------------------------|-----------------------------------------------------|--------|
| Fever                     | Do you have a fever?                                | 0.8    |
| Fever less than three days| Is the fever happens less than three days?          | 0.2    |
| Rashes on Hand            | (because the certainty factor process can’t start if the rashes not detected, this symptom doesn’t have question and the answer is always yes) | 0.8    |
| Rashes filled with liquid | Are the rashes on the palm filled with liquid?      | 0.6    |
| Rashes are red            | Are the rashes on the palm red?                    | 0.6    |
| Rashes also showed up on foot and mouth | Are the rashes also showed up on foot and mouth? | 0.8    |
| Rashes felt painful       | Are the rashes felt painful?                        | 0.2    |
| Rashes felt itchy         | Are the rashes felt itchy?                         | 0.2    |
Meanwhile, for determining the threshold for deciding whether the symptoms indicates HFMD or not, author has calculate the certainty factor of 96 possible answer from a dataset, and search for highest not indicated HFMD number and lowest indicated HFMD number. Dataset is a combination of all the possible answer that follows the rules and also has been validated by the expert.

Figure 1. Dataset of Possible Answers
Figure 1 is Dataset that has been validated by expert. It contains 96 possible answers and the outcome(result) of the answers. After calculating all of the CF, we found out that the highest CF for not indicated is 0.9967232 while the lowest CF for indicated is 0.9968. By that, we can decide the threshold for classifying whether the symptoms are indication of HFMD or not. For the implementation, we decided to use 0.9968 as the threshold.

2.4. System Overview
As shown on figure 2, after the other system detected rashes on palmprint, this system can start the Interview process. User can answer yes or no and the system will start calculating CF. Last page of this application will show the information on whether user is indicated for HFMD or not.

In addition to system overview, figure 3 shown the detailed flow of the system. First, user will get question which they will answer based on their symptoms. Then, the system will start calculating the CF of each answers. After doing iteration as much as the number questions, system will then give the output in form of information.

2.5. Confusion Matrix
For measuring the accuracy of this method we need to use confusion matrix. Variable of confusion matrix that is used in this paper are Accuracy, Precision, and Recall. Dataset used for this confusion matrix is shown on figure 1.

| Predicted | Actual |
|-----------|--------|
| Not Indicated for HFMD | Indicated for HFMD |
| Not Indicated for HFMD | A | B |
| Indicated for HFMD | C | D |
Formula to calculate Accuracy, Precision, and Recall are shown below [11]:

\[
\text{Accuracy} = \frac{A + D}{A + B + C + D} \times 100\%
\] (6)

\[
\text{Precision} = \frac{D}{B + D} \times 100\%
\] (7)

\[
\text{Recall} = \frac{D}{C + D} \times 100\%
\] (8)

Accuracy is used to count how much this certainty factor method correctly classify user’s answers. Precision is used to calculate how many correct “You are indicated to HFMD” output that are issued. In addition to that, recall is for counting the percentage of how much this system used the dataset effectively.

3. Result and Discussion

To test the validity of this system, we compare the result of the application and the result of calculating manually. To test the functionality of this application, we make two examples of case. The first case is as follows:

Table 5. Example 1
Based on the answers from example 1 which is shown on table 4, we can calculate the CF value manually using the formula 3 and 4.

\[
\begin{align*}
C_{F_{\text{total}}} & = 0.8 + 0.2 \cdot [1 - 0.8] = 0.967232 \\
C_{F_{\text{total}}} & = 0.8 + 0.2 \cdot [1 - 0.8] = 0.967232 \\
C_{F_{\text{total}}} & = 0.84 + 0.6 \cdot [1 - 0.84] = 0.984 \\
C_{F_{\text{total}}} & = 0.936 + 0.6 \cdot [1 - 0.936] = 0.9744 \\
C_{F_{\text{total}}} & = 0.9744 + 0.6 \cdot [1 - 0.9744] = 0.99488 \\
C_{F_{\text{total}}} & = 0.99488 + 0.2 \cdot [1 - 0.99488] = 0.995904 \\
C_{F_{\text{total}}} & = 0.995904 + 0.2 \cdot [1 - 0.995904] = 0.9967232
\end{align*}
\]

**Figure 1. Manual Calculation for Example 1**

As shown on figure 5, total CF of the symptoms is 0.9967232 and can be classified as not indicated to HFMD. In addition to the manual calculation, we also did the example on the application which gives the result shown on figure 6.
Next, we try the calculation for example 2 with new case:

**Figure 5. Result from Application**

**Table 6. Example 2**

| Questions (because the certainty factor process can’t start if the rash is not detected, this symptom doesn’t have question and the answer is always yes) | Answer | Weight |
|---|---|---|
| Do you have a fever? | YES | 0.5*1=0.5 |
| Is the fever happened less than three days? | NO | 0.2*0=0 |
| Are the rash on the palm filled with liquid? | YES | 0.5*1=0.5 |
| Are the rash on the palm red? | YES | 0.5*1=0.5 |
| Are the rash also showed up on foot and mouth? | NO | 0.2*0=0 |
| Are the rash felt painful? | NO | 0.2*0=0 |
| Are the rash felt itchy? | NO | 0.2*0=0 |

Manual calculation of the CF for answers on example 2 is below, using the same formula as before.

\[
CF_{result} = CF_{result}[\text{Hand,Foot and Mouth Disease}] = 0.8 + 0.8 \times [1 - 0.8] = 0.96 \\
CF_{result} = CF_{result}[\text{Hand,Foot and Mouth Disease}] = 0.6 + 0.3 \times [1 - 0.96] = 0.96 \\
CF_{result} = CF_{result}[\text{Hand,Foot and Mouth Disease}] = 0.56 + 0.6 \times [1 - 0.96] = 0.96 \\
CF_{result} = CF_{result}[\text{Hand,Foot and Mouth Disease}] = 0.5 + 0.6 \times [1 - 0.96] = 0.96 \\
CF_{result} = CF_{result}[\text{Hand,Foot and Mouth Disease}] = 0.50 + 0.6 \times [1 - 0.96] = 0.96 \\
CF_{result} = CF_{result}[\text{Hand,Foot and Mouth Disease}] = 0.50 + 0.6 \times [1 - 0.96] = 0.96 \\
CF_{result} = CF_{result}[\text{Hand,Foot and Mouth Disease}] = 0.50 + 0.6 \times [1 - 0.96] = 0.96 \\
\]

**Figure 2. Manual Calculation for Example 2**

Result of manual calculation for example 2 is 0.9936 which means that user from example 2 is not indicated to HFMD. Let’s compare the result to the calculation done by application that shown in figure 8.
After the implementation of Certainty Factor as expert system method on android based phone and doing the testing both manually and by application, we can calculate the Accuracy, Precision, and Recall from the confusion matrix.

**Table 7. Confusion Matrix with result**

| CF Expert | Not Indicated for HFMD | Indicated for HFMD |
|-----------|-------------------------|--------------------|
| Not Indicated for HFMD | 72 | 0 |
| Indicated for HFMD | 0 | 24 |

\[
\text{Accuracy} = \frac{72 + 24}{72 + 0 + 24} \times 100\% = 100\%
\]
\[
\text{Precision} = \frac{24}{0 + 24} \times 100\% = 100\%
\]
\[
\text{Recall} = \frac{24}{0 + 24} \times 100\% = 100\%
\]

Based on the calculation above, the percentage on how much the certainty factor method be able to classify user’s answers is 100%, meanwhile, the percentage on how many correct “You are indicated to HFMD” output that are issued is also 100%. Lastly, the percentage of how many this system (using certainty factor method) uses the “Detected to HFMD” dataset effectively is 100%.

4. **Conclusion**
Certainty Factor as expert system method used for early detection of HFMD based on Android phone has accuracy value of 100% which means that this method can correctly classify user’s answers. The percentage on how many correct “You are indicated to HFMD” output from this system is also 100%. In addition to that, the system ability to uses the “Detected to HFMD” dataset effectively is 100%.

The usage of correct and precise dataset helped a lot in making of this application. As for the next research, try to minimize the dataset so this system performance based on the dataset could be tested.

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