A Combination of Forward Chaining and Certainty Factor Methods for Early Detection of Fever: Dengue Hemorrhagic Fever, Malaria, and Typhoid

by Zilvanhisna Emka Fitri

A Combination of Forward Chaining and Certainty Factor Methods for Early Detection of Fever: Dengue Hemorrhagic Fever, Malaria, and Typhoid

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Abstract.

Purpose: Dengue Hemorrhagic and Malaria fevers are the most common arthropod-borne diseases caused by mosquito bites and they also have similar signs and symptoms. Based on the problems, the researcher makes an expert system that aims to help people early detect fever diseases. This system is expected to help and support the infectious disease prevention and control program by the Ministry of Health of the Republic of Indonesia.

Methods: This study uses an expert system with a combination of Forward Chaining and Certainty Factor to detect the symptoms of fever. Forward Chaining is a technique that begins with gathering information related to known facts, then combining rules to produce conclusions. The certainty Factor method is used to define a measure of certainty against a fact or rule and to describe the level of expert confidence in dealing with problems. There are 32 symptoms of the disease consisting of dengue fever, malaria and typhoid, it was obtained based on the literature and interviews with internal medicine specialist with 20 case datasets.

Result: Based on 20 test data, obtained one data that does not match the test results and the desired target so that the system accuracy obtained is 95%. In addition, the combination of Forward Chaining and Certainty factor has better accuracy when compared to expert systems in previous studies.

Novelty: Forward Chaining to find three rules and assigning weights to the Certainty Factor that has been set by the expert makes the combination of the two methods produce better accuracy.

Keywords: Early Detection of Fever, Forward Chaining, Certainty Factors

INTRODUCTION

Dengue Hemorrhagic Fever (DHF) is a disease caused by the dengue virus which is transmitted through the bite of the Aedes aegypti mosquito. This disease is generally found in tropical areas such as Indonesia and often causes Extraordinary Events (outbreaks)[1]. Based on data from Dinas Kesehatan Provinsi Jawa Timur, the Incidence Rate of Dengue Hemorrhagic Fever in East Java in 2019 was 47/100,000 population and increased compared to 2018 which was 24/100,000 population. However, compared to the incident rate set nationally (the national target is less than 49/100,000 population), the incident rate in East Java is still lower than the national target. Although in 2019, cases of DHF have increased compared to last year before, but still needs to be increased vigilance against spikes in cases in each period so that it is hoped that there will be no extraordinary events (outbreaks)[2].

Several factors that influence the transmission of dengue cases in East Java are population density, population mobility, urbanization, economic growth, community behavior, changes in climate, environmental sanitation conditions, and the availability of clean water. One of the strategic efforts to prevent and control dengue fever is to increase the early diagnosis of dengue fever[2]. Problems that often occur in the community are related to delays in the diagnosis process due to a lack of public knowledge of the symptoms of dengue fever. Generally, dengue hemorrhagic fever is characterized by a fever of 4-7 days, even though some accompanying symptoms such as headache, back pain, pain when moving the eyeballs

and sometimes accompanied by signs of bleeding because the incubation period of dengue fever is 3-14 days [1]. Malaria is caused by mosquito-borne Plasmodium parasites, with P. vivax and P. falciparum. Human infection with Plasmodium parasites can cause mild to severe illness, encompassing a wide variety of symptoms including fever, headache, malaise, anemia, sweats, and chills that first appear 7–10 days after a bite from an infected mosquito [3]. Typhoid fever, which is caused by *Salmonella typhi* and 3 types of *Salmonella paratyphi* also share similar symptoms with both malaria and dengue fevers [4]. Based on the description of the above problems, the researcher makes an expert system that aims to help people in the early detect diseases such as dengue hemorrhagic fever, malaria and typhoid. This system is expected to help and support the infectious disease prevention and control program that has been carried out by the Ministry of Health of the Republic of Indonesia.

Several references related to the dengue hemorrhagic fever expert system that became the reference for researchers, namely the application of the Certainty Factor method for the diagnosis of Dengue Hemorrhagic Fever resulted in a CF of 80.909%[5], 90.4%[6], 97.6% [7] and 100% [8] so that the Certainty Factor method is able to properly diagnose Dengue Hemorrhagic Fever based on its symptoms. The next research is to compare the bayes method and the certainty factor method in the early detection of dengue infection, so that the bayes method accuracy rate is 90% while the certainty factor method has an accuracy rate of 93.75% [9]. Another expert system method used for the diagnosis of Dengue Hemorrhagic Fever is forward chaining. The Forward Chaining method is a search method or forward tracking technique that begins with collecting existing information about an object and combining rules to produce conclusions or goals [10], [11], for example, the diagnosis of Covid-19 in Indonesia[12], the diagnosis of eye diseases[13] and diagnose child development growth disorders[14]. This method does not run alone but usually collaborates with other methods such as decision trees when running the expert system rules[10], [15]. Combining the forward chaining method and certainty factor has also been carried out to identify other diseases such as pertussis in children with CF of 97%[16] and diagnose digestive tract diseases in children with CF of 80.5%[17]. This method is better than combining the K-Nearest Neighbor – Certainty Factor method for the diagnosis of fever: DHF, Malaria and Typhoid, with an accuracy rate of 84.79%[18].

Based on the reference description above, the researchers developed an expert system for early detection of fever, namely Dengue Hemorrhagic Fever, Malaria and Typhoid by combining the Forward Chaining Method and Certainty Factor.

METHODS
This expert system consists of several stages, namely problem identification, literature study, data collection, making a fever expert system, system testing, and system analysis as shown in Figure 1.

Figure 1. The Block Diagram on Fever Expert System Research

Identification of Problems
There is often a delay in the diagnosis process, due to a lack of public knowledge of the symptoms of Dengue Hemorrhagic Fever, which is generally characterized by fever but some accompanying symptoms such as headache, back pain, pain when moving the eyeballs and sometimes accompanied by signs of bleeding. In addition, fever also describes the symptoms of other diseases such as malaria and typhoid. To assist the early detection process, an expert system for dengue hemorrhagic fever was created.

Study of Literature

Literature study is an activity carried out by researchers to solve problems by tracing previous reference sources. The topics related to this research are the knowledge base related to the symptoms of dengue hemorrhagic fever, malaria and typhoid. The expert system used is a combination of forward chaining method and certainty factor method.

Data Collection

Data collection methods used include library research and interviews. In this research, researchers interviewed dr. Agus Yudha Santosa, Sp.PD FINASIM who specializes in internal medicine at Siloam Jember Hospital. He validated some symptom data that we had obtained from observations of several books and journals related to the symptoms of dengue fever, malaria and typhoid. In addition, he provides procedures or rules and weights for each symptom that is used as a knowledge base on the expert system that we developed. Based on the results of the interview, 20 data samples were obtained with symptoms of dengue hemorrhagic fever, malaria and typhoid. The data obtained is a list of disease names and codes (Table 1) as well as some of the symptoms that accompany the disease. Because this research uses the certainty factor method, the CF value is obtained from an expert or specialist in internal medicine as shown in Table 2.

Table 1. The code name of disease and illness

Number	Disease Code	Disease Name
1	P01	Dengue Hemorrhagic Fever
2	P02	Malaria
3	P03	Typhoid

Table 2. CF value from experts for each disease symptoms

No	Symptom Code	Name of Disease Symptoms	Expert CF Value
1	G01	Fever for 2 -7 days	1
2	G02	Fever with a temperature of 39° - 40℃	1
3	G03	Heartburn	0.6
4	G04	Anorexia (Eating Disorder)	[0.4][0][0.2]
5	G05	Petechiae (rash or red spots on the skin)	0.4
6	G06	Shock	0.4
7	G07	Nosebleed	0.6
8	G08	The number of platelets < 100,000 / mm^3	0.8
9	G09	Constipation	0.8
10	G10	Significant temperature rise	1
11	G11	Bleeding cough	0.4
12	G12	Fever more than 2 days	1
13	G13	Fever at 37.5° / 40℃	1
14	G14	Lethargy or fatigue	0.4
15	G15	Muscle Paralysis	0.2
16	G16	Joint pain	0.2
17	G17	Changes in the color of urine like the color of tea	0.2
18	G18	Anemia	0.2
19	G19	Bad Appetite	0.6
20	G20	Dehydration	0.8
21	G21	Skin turns yellow	0
22	G22	Having a seizure	0.2
23	G23	Fever more than 7 days	0.4
24	G24	Fever with a temperature of 40.5°Celsius	0.8
25	G25	Headache	0.6
26	G26	Muscle ache	0.6
27	G27	Nausea	0.2
28	G28	Fever starts from low temperature and increases every day	1
29	G29	Stomach ache	0.2
30	G30	The tongue is covered with a dirty white membrane	0.2
31	G31	The edge of the tongue is reddish	0.2
32	G32	Tremor	0.2

Fever Expert System

An expert system is a system that adopts knowledge from humans or experts so that the system can solve problems as experts do[19]. The components needed in building an expert system are working memory,

user interface, Inference machine and knowledge base[18]. In this research, two methods are used, namely forward chaining and certainty factor. Forward Chaining is a forward search technique that begins with gathering information related to known facts, then combining rules to produce conclusions[20]. The basic rules of forward chaining are the IF –THEN rules[10] as shown in Figure 2.
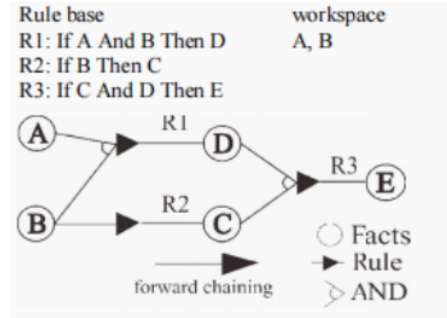

Figure 2. The basic rules of the forward chaining method[10]

While the certainty factor method is used to define a measure of certainty against a fact or rule and to describe the level of expert confidence in dealing with problems[6]. The following is the equation for the certainty factor method[9] :

$$CF[h, e] = MB[h, e] - MD[h, e] \qquad (1)$$

CF[h,e] = Certainty factor
MB[h,e]= Measure of belief, a measure of the level of confidence in the hypothesis (h), if given evidence (e) between 0 and 1
MD[h,e]= Measure of disbelief, a measure of distrust or the level of confidence in the hypothesis (h), if given evidence (e) between 0 and 1.

There are several combinations of certainty factors for certain premises :

$$CF[h, e] = CF[e] * CF[rule] = CF[rule] * CF[expert] \qquad (2)$$

a. Certainty Factor with more than one premise.

$$CF[A \cap B] = Min(CF[a], CF[b] * CF[rule] \qquad (3)$$
$$CF[A \cup B] = Max(CF[a], CF[b] * CF[rule] \qquad (4)$$

b. Certainty factor with a similar conclusion.

$$CF_{combination}[CF1, CF2] = CF1 + CF2 * (1 - CF1) \qquad (5)$$

RESULT AND DISCUSSION
One of the important components in a fever expert system is the design of the user interface. An example of a fever expert system is the consultation page in Figure 3 and the consultation results page in Figure 4. Figure 3 shows the fever consultation page, where the user will consult and detect dengue fever, malaria and typhoid based on the symptoms experienced by the user. The user will be given several questions and required to fill in all the questions (total number of questions is 33 questions). Figure 4 shows a display containing the symptoms selected by the patient. Based on these symptoms, the results show that the patient or user is detected early on dengue hemorrhagic fever, malaria or typhoid. These results are indicated by the percentage of the possible disease that is being suffered by the patient or user. The percentage is obtained based on the calculation of the Certainty Factor method.

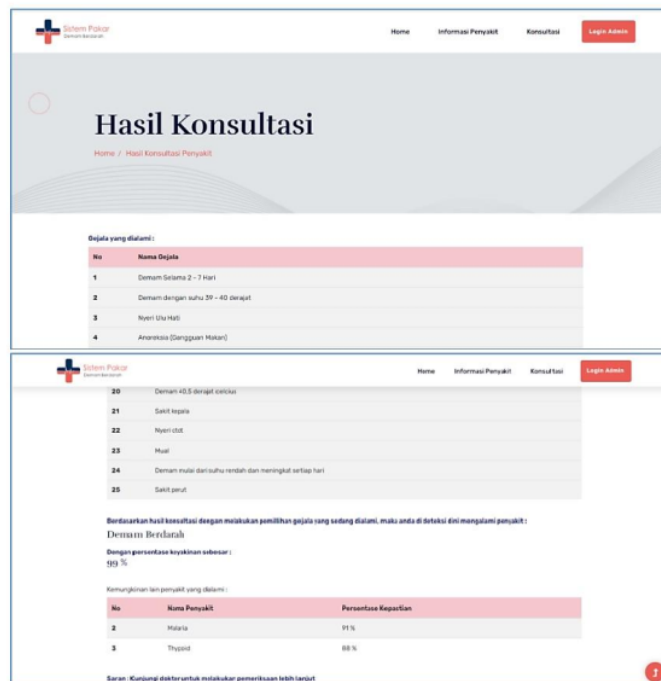Figure 3. Consultation display on the Expert System for Early Detection of Fever

Figure 4. Display on the consultation results page

Forward Chaining Rules

In this research, Table 1 is about the disease code and the name of the disease, then Table 2 is about the symptom code and the CF value from the expert. The next step is to make data related to the rules used in the search for diseases based on the selected symptoms. These rules use the Forward Chaining method shown in Table 3.

Table 3. Forward Chaining Rules

No	Code	Rule
1	A01	IF [G01] AND [G02] AND [GO3] AND [G04] AND [G05] AND [G06] AND [G07] AND [G08] AND [G09] AND [G10] AND [G11] THEN P1
2	A02	IF [G12] AND [G13] AND [G14] AND [G15] AND [G16] AND [G17] AND [G18] AND [G19] AND [G20] AND [G21] AND [G22] THEN P2
3	A03	IF [G23] AND [G24] AND [G25] AND [G26] AND [G27] AND [G04] AND [G29] AND [G29] AND [G30] AND [G31] AND [G32] THEN P3

The Expert System Calculations

The calculation of the system is done by entering one case example into the calculation. In this case, the user selects the symptoms experienced and enters the CF value and compares it with the CF from the Expert as shown in Table 4.

Table 4. Code and name of the symptoms selected by the user

No	Symptom Code	Name of Disease Symptoms	User CF Value	Expert CF Value
1	G01	Fever for 2 -7 days	1	1
2	G02	Fever with a temperature of 39° - 40°C	0.8	1
3	G03	Heartburn	1	0.6
4	G04A	Anorexia (Eating Disorder)	0.4	0.4
5	G05	Petechiae (rash or red spots on the skin)	0.8	0.4
6	G06	Shock	0.2	0.4
7	G07	Nosebleed	0.8	0.6
8	G08	The number of platelets < 100,000 / mm^3	0.8	0.8
9	G10	Significant temperature rise	0.8	1
10	G12	Fever more than 2 days	0.8	1
11	G13	Fever at 37.5° / 40°C	1	1
12	G14	Lethargy or fatigue	0.8	0.4
13	G15	Muscle Paralysis	0.8	0.2
14	G16	Joint pain	0.8	0.2
15	G17	Changes in the color of urine like the color of tea	0.6	0.2
16	G19	Bad Appetite	0.2	0.6
17	G20	Dehydration	0.6	0.8
18	G04B	Anorexia (Eating Disorder)	0.2	0.2
19	G23	Fever more than 7 days	0.4	0.4
20	G25	Headache	0.6	0.6
21	G26	Muscle ache	0.6	0.6
22	G27	Nausea	0.8	0.2
23	G28	Fever starts from low temperature and increases every day	0.6	1
24	G29	Stomach ache	0.6	0.2

The next step is to calculate the certainty factor of each existing rule, by determining the rule that has the highest possible percentage value. Determination of the rule by grouping the data and CF values of symptoms that have been selected by the user as follows :

Rule 1 : G01, G02, G03, G04A, G05, G06, G07, G08, G010

Rule 2 : G12, G13, G14, G15, G16, G17, G19, G20

Rule 3 : G04B, G23, G24, G25, G26, G27, G28, G29

A. Calculation of Rule 1

In the calculation of Rule 1 as described in Table 3, namely 'IF [G01] AND [G02] AND [GO3] AND [G04] AND [G05] AND [G06] AND [G07] AND [G08] AND [G09] AND [G10] AND [G11] THEN P1' then the equations of formulas (2), (5) are used and to find the probability percentage of the rule is calculated using the equations of formulas (6) so that the results are as in Table 5.

$$CF[h, e] = CF[rule] * CF[expert] \tag{2}$$

$$CF_{combination}[CF1, CF2] = CF1 + CF2 * (1 - CF1) \tag{5}$$

$$\% \, Persentase \, rule = Highest \, of \, CF_{combination} * 100\% \tag{6}$$

Table 5. The result of the calculation rule 1

No.	CF Symptom	CF Combine	Percentage Rule 1
1.	0.4	0.59	
2.	0.32	0.76	
3.	0.4	0.77	
4.	0.08	0.92	
5.	0.64	0.93	
6.	0.08	0.95	99%
7.	0.32	0.98	
8.	0.64	0.98	
9.	0	0.99	
10.	0.32	0.99	
11.	0	-	

B. Calculation of Rule 2

In the calculation of Rule 2 as described in Table 3, namely 'IF [G12] AND [G13] AND [G14] AND [G15] AND [G16] AND [G17] AND [G18] AND [G19] AND [G20] AND [G21] AND [G22] THEN P2' and the results of the calculation of Rule 2 are shown in Table 6.

Table 6. The result of the calculation rule 2

No.	CF Symptom	CF Combine	Percentage Rule 2
12.	0.48	0.69	
13.	0.4	0.79	
14.	0.32	0.82	
15.	0.16	0.88	
16.	0.32	0.89	
17.	0.12	0.89	91%
18.	0	0.90	
19.	0.08	0.91	
20.	0.12	0.91	
21.	0	0.91	
22.	0	-	

C. Calculation of Rule 3

In the calculation of Rule 3 as described in Table 3, namely 'IF [G23] AND [G24] AND [G25] AND [G26] AND [G27] AND [G04] AND [G29] AND [G29] AND [G30] AND [G31] AND [G32] THEN P3' and the results of the calculation of Rule 3 are shown in Table 7. Based on the calculation results of the three rules, the percentage of possible diseases, namely dengue hemorrhagic fever is 99%, malaria is 91% and typhoid is 88%. So it can be concluded that the user is experiencing symptoms of dengue hemorrhagic fever.

Table 7. The result of the calculation rule 3

No.	CF Symptom	CF Combine	Percentage Rule 3
23.	0.08	0.30	
24.	0.24	0.33	
25.	0.04	0.49	
26.	0.24	0.61	
27.	0.24	0.74	
28.	0.32	0.86	88%
29.	0.48	0.88	
30.	0.12	0.88	
31.	0	0.88	
32.	0	0.88	
33.	0	-	

Testing The System

System testing is a stage that is carried out after the system implementation process has been implemented. Accuracy testing on the system is carried out to determine the level of accuracy of the expert system for early detection of dengue fever. The system testing was carried out with 20 data and the results of system testing are shown in Table 8. Those table shows that of the 20 test data, there is 1 data whose results are not in accordance with the results of the expert.

Table 8. Fever expert system test results

No	Result	Percentage (%)	the suitability of the test data with the expected target	
			Match	Not Match
1.	Dengue Hemorrhagic Fever	99	✓	
2.	Dengue Hemorrhagic Fever	96	✓	
3.	Dengue Hemorrhagic Fever	90		✓
4.	Dengue Hemorrhagic Fever	98	✓	
5.	Dengue Hemorrhagic Fever	98	✓	
6.	Dengue Hemorrhagic Fever	97	✓	
7.	Dengue Hemorrhagic Fever	98	✓	
8.	Dengue Hemorrhagic Fever	99	✓	
9.	Malaria	96	✓	
10.	Malaria	92	✓	
11.	Malaria	92	✓	
12.	Malaria	94	✓	
13.	Malaria	96	✓	
14.	Malaria	90	✓	
15.	Typhoid	99	✓	
16.	Typhoid	99	✓	
17.	Typhoid	98	✓	
18.	Typhoid	99	✓	
19.	Typhoid	97	✓	
20.	Typhoid	99	✓	

Analysis

To get the percentage of the system accuracy results in early detection of dengue fever, you can use the following formula:

$$Accuracy = \frac{The\ number\ of\ the\ corresponding\ test\ data}{Total\ number\ of\ test\ data} x\ 100\% \qquad (7)$$

$$Accuracy = \frac{19}{20} x\ 100\% = 95\%$$

Based on the test results in Table 8, of the 20 test data, there is 1 data whose results are not following the results of the expert. The level of accuracy in the expert system using a combination of forward chaining methods and certainty factor is 95%. Based on these results, it is known that the combination of forward chaining method and certainty factor can distinguish the symptoms of dengue fever, malaria and typhoid with an accuracy of 95%. This accuracy is better than the previous method, namely Naive Bayes with an accuracy of 90% and a certainty factor of 93.75%.

CONCLUSION

Based on the results of the expert system research for early detection of dengue fever, it was concluded that the combination of Forward Chaining and Certainty Factor methods was able to detect early symptoms of dengue, malaria, and typhoid fever with a system accuracy rate of 95%.

ACKNOWLEDGEMENT

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FINAL GRADE

/0

GENERAL COMMENTS

Instructor