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Optimizing the Combination of Forward Chaining and Certainty Factor Methods in Early Diagnosis of Tertiana and Tropical Malaria Diseases

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Abstract: Plasmodium falciparum and Plasmodium vivax parasites cause malaria, which is spread through the bite of infected mosquitoes. Headache, high fever, diarrhea, rapid pulse, rapid breathing, and vomiting are symptoms of malaria. Malaria is even potentially fatal because it causes heart, kidney, and even brain damage, so it is necessary to detect malaria early. This research is expected to help users detect malaria earlier and get an early diagnosis. Optimization of the combination of forward chaining and certainty factor methods in the early diagnosis of tertiana and tropical malaria diseases obtained the results of the selection of symptoms tested by patients obtained an early diagnosis of Tropical Malaria Disease by 40% and Tertiana Malaria by 72.9%. The system parameters entered are based on the symptoms of malaria. Furthermore, the forward chaining algorithm and certainty factor are used to determine the type of malaria that the user may suffer from the data that has been entered. The test results show an average accuracy rate of 90% from fifty patient samples with various data variants, which shows that the system has worked well.

Keywords: *Certaintu factor, forward_chaining, malaria, expert_system, Atificial_intelligent*

1. Introduction

An expert system is one of the branches of science on Artificial Intelligence that adopts the knowledge of an expert into a computer that models knowledge in solving problems like an expert [1]. Malaria is still a unique problem nationally and globally, especially in malaria endemic areas, namely Papua [2][3][4]. Malaria remains a significant public health problem in many countries, especially in the tropics. Malaria can have serious consequences, including death, if not diagnosed and treated in a timely manner [5][6]. Papua Province is one of the provinces that still has a high incidence of malaria in Indonesia. According to data from the Indonesian Ministry of Health in 2020, Papua Province is among the 10 provinces with the highest malaria cases in Indonesia with 14,149 cases. In some areas of Papua, malaria prevalence rates exceed 75%, indicating high transmission intensity throughout the year [7]. The most common types of malaria found in Jayapura city are tropical malaria caused by the parasite Plasmodium falciparum and tertiana caused by the parasite Plasmodium vivax or Plasmodium ovale. Early diagnosis and appropriate treatment are key to reducing the impact of malaria on health, [8][9][10] especially in Papua.

This research case study takes place at the Twano Health Center, which is one of the pilot health centers in Jayapura. The number of Malaria patients has increased significantly every month so an intelligent system is needed to help the general public in diagnosing early what type of malaria they are experiencing [11]. The problem that currently occurs is the lack of optimization of methods in early diagnosis of malaria.

Expert System for Early Diagnosis of Tropical and Tertiana Malaria [12] so an Artificial Intelligence-based expert system is created that can help doctors and medical personnel in diagnosing early malaria tropical malaria and tertiana malaria. Optimizing the combination of the Forward Chaining and Certainty Factor methods is one approach that can be used to develop the expert system. The Forward Chaining method is used to build an inference system that can generate conclusions based on facts provided by users, a collection of IF-THEN rules is used to build a knowledge base [13]. While the Certainty Factor is used to measure the level of certainty or confidence of each conclusion generated by the system.

Previous studies on the use of Forward Chaining and Certainty Factor methods have been used in various fields and different case studies. The first study using the Forward Chaining method to diagnose the effects of mosquito bites diagnosed diseases such as dengue fever, malaria, chikungunyah, jaundice fever, encephalitis, and elephantiasis (filariasis) with the use of the method has resulted in a diagnosis success rate of 80-98% [14]. The second research is to detect the type of road damage using the Forward Chaining technique which in this case wants to know in advance the type of road damage so that to form a rule base must already have data, namely data on the characteristics and types of road damage for flexible pavement obtained from documents and expert validation,

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namely the technical team of road repair, for the results of the research has an accuracy rate of 60% [15]. The third research is the utilization of the Certainty Factor method in diagnosing Osteochondroma disease based on a knowledge base with a certainty level of 97% for Chronic Osteochondroma disease [16]. The fourth research is the implementation of the Certainty Factor method on an expert system to diagnose PC damage which in utilization has a certainty value of 88% with the conclusion that the computer damage that occurs is in RAM, the results of this study are information on damage to computer PC hardware and solutions to overcome the damage [17]. Furthermore, the fifth research is to create a knowledge base in diagnosing diabetes mellitus, this article explains how an expert system can diagnose diabetes mellitus in the form of a table containing 62 parameters and 27 rules [18]. The next research describes the identification process using fuzzy logic rules and threshold estimates obtained from Certainty Factor, based on a CF expert system with uncertain rules and imprecise active variables presented to identify abnormalities in complex industrial processes [19]. Future research aims to evaluate the role of artificial intelligence in the bank lending process in supporting banking decision-making [20]. For the final research referenced regarding the Expert Automated System for Multi-Type Dermatological Disease Prediction Using Deep Neural Network Feature Extraction Approach, which aims to accurately anticipate skin diseases while storing all related state data efficiently and effectively for precise forecasts. The research that will be built is a development on the 2021 pdp grant, researchers have conducted research that only uses the Certainty Factor method in determining the type of malaria in patients [21].

Based on the summary of previous studies, it was found that there was no use and optimization of the combination of the Forward Chaining and Certainty Factor methods, in the development of research using a combination of these methods will provide optimal and more accurate results in the early diagnosis of tropical and tertiana malaria. The virtue of early diagnosis of malaria can avoid the development of the disease into a more severe stage and reduce treatment costs. Therefore, optimizing early diagnosis methods is very important. Accuracy of diagnosis is a key factor in the treatment of this disease. The combination of Forward Chaining and Certainty Factor methods can help improve accuracy by combining clinical information with the level of certainty associated with the observed symptoms. Optimizing the combination of Forward Chaining and Certainty Factor methods in the early diagnosis of tertiana and tropical malaria is relevant and has the potential to improve the quality of health services and patient outcomes. The results of this study are in the form of manual calculations of the optimization of the combination of the Forward Chaining and Certainty Factor methods which will be compared with the diagnosis results of an expert or doctor as well as accuracy results using sample testing from 50 patients to be tested.

2. Research Method

2.1. Research Chronology

Broadly speaking, this research has several important stages, as for the research stages described in the chart as in Figure 1. Based on Figure 1, shows the chronology of research including data collection through observation, literature study, then the forward chaining optimization process consists of several steps, namely displaying the type of malaria disease, identifying symptoms of malaria disease, creating a knowledge base based on the relationship between types of malaria disease, creating disease rules based on forward chaining rules with rules (IF-THEN), then optimization through the certainty factor (CF) process starting with determining the MB and MD weight values, calculating the CF value of each symptom, calculating the CF value of the combination of each disease, and testing.

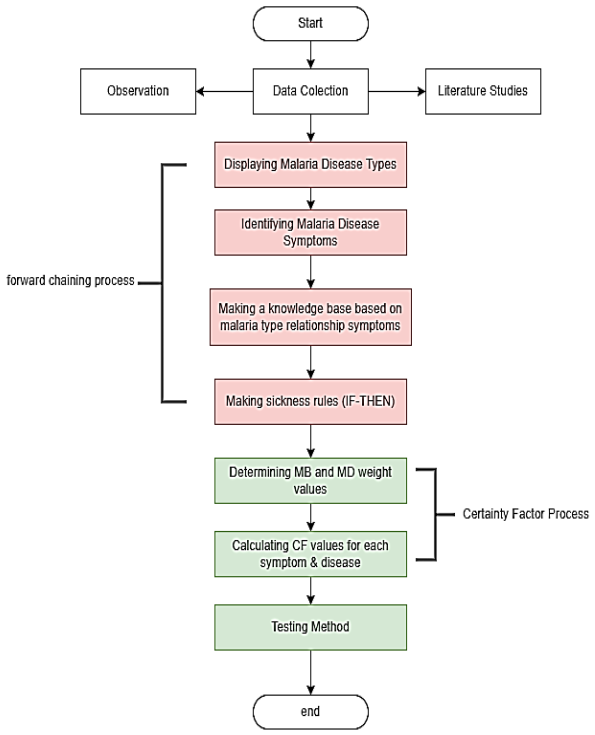

Fig 1. Research Activities

2.2. Forward Chaining

Forward Chaining is one of the most commonly used expert system methods [22][23]. The use of forward motion by collecting facts with search techniques to produce conclusions to become a solution to the existing problem [24]. The work process of the Forward Chaining method is the use of the appropriate facts in the IF section then the rule can be executed. After the rule is executed, a new fact (THEN part) is added to the database. The initial of the top rule every time it is matched and each rule can only be executed once. If there are no more rules that can be

executed then the matching process stops. Figure 2 shows the Forward Chaining process.

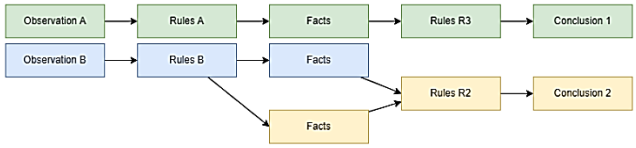

Fig 2. Forward Chaining Process

2.3. Certainty Factor

Certainty Factor can prove a fact is certain or uncertain which is formed in a metric that is usually used in expert systems [25], [26]. This is an advantage of the Certainty Factor method which can measure something definite or uncertain to make decisions on disease diagnosis expert systems [27]. Here's how to determine the CF value and combine CF values [28], [29].

a) Determine the Certainty Factor Value

Here are 2 ways to get the Certainty Factor confidence value from a data, namely:

1. The net belief method proposed by E.H. Shortliffe and B.G. Buchanan

$$MB(H|E)=\left\{\frac{MAX(H|E),P(H)-P(H)}{MAX[1,0]-P(H)}\right\} P(H)=1 \quad (1)$$

$$MD(H|E)=\left\{\frac{MIN(H|E),P(H)-P(H)}{MIN[1,0]-P(H)}\right\} P(H)=1$$

$$CF[H,E]=MB[H,E]-MD[HE] \quad (3)$$

Description:

CF Rule : Certainty Factor

MB (H|E) : Measure of belief in hypothesis H, given evidence E (between 0 and 1)

MD (H|E) : Measure of disbelief in hypothesis H, given evidence E (between 0 and 1)

P(H) : Probability of truth of hypothesis H

P(H|E) : Probability that H is true due to fact E

2. By interviewing an expert

The CF value for each symptom is obtained from the "tern" interpretation of the expert, which is converted into a specific CF value according to the following table:

Table 1. Expert's "tern" Interpretation Value

Uncertain Tern	CF
Definitely not	-1.0
Almost certainly not	-0.8
Probably not	-0.6
Probably not	-0.4
Don't know	-0.2 to 0.2
Probably	0.4
Most likely	0.6
Almost certain	0.8
Definitely	1.0

b) Combining Certainty Factor Values

Certainty Factor for rules with similarly concluded rules:

CFcombineCF[H,E]1,2 = CF[H,E]1 + CF[H,E]2 * [1-CF[H,E]1]

CFcombineCF[H,E] old,3 = CF[H,E]old + CF[H,E]3 * [1-CF[H,E]old] (2)

3. Result and Discussion

3.1. Diseases and Knowledge Base

One of the problems in knowledge-based systems is handling conflicting information [30]. This research case study takes place at the Twano Health Center, which is one of the pilot health centers in Jayapura. The number of Malaria patients has increased significantly every month so an intelligent system is needed to help the general public in diagnosing early what type of malaria they are experiencing.

Optimizing the combination of Forward Chaining and Certainty Factor methods is one approach that can be used to develop the expert system. The Forward Chaining method is used to build an inference system that can generate conclusions based on facts provided by the user. While the Certainty Factor is used to measure the level of certainty or confidence of each conclusion generated by the system.

Table 2. Knowledge Base

Knowladge Base				
Code Knowledge	**Code Disease**	**Disease Name**	**Code Symptom**	**Symptom Name**
1	MTE1	Tertian Malaria	G01	Live in an endemic area
			G02	Severe shivering when body temperature rises during a fever attack.
			G03	Severe headache and severe pain.
			G04	Feeling tired and weak during a fever attack or afterward.
			G05	Muscle and Joint Pain
			G06	After the fever phase, sufferers often experience excessive sweating which is very annoying.
			G07	Anemia: which can be seen from pale skin
			G08	Fever appears in a three-day cycle, namely every 48 hours (first day fever, second day no fever, third day fever returns).
			G09	Often have difficulty concentrating or are confused during fever attacks.
2	MTO2	Tropical Malaria	G10	Fever can appear without a specific cycle and fever attacks can be more frequent.
			G02	Severe shivering when body temperature rises during a fever attack.
			G11	Severe headaches such as migraines are common.
			G12	Symptoms of nausea and vomiting are often accompanied by fever
			G04	Feeling very weak and tired during and after a fever attack.
			G13	Weight Loss: Loss of appetite and vomiting can cause weight loss.
			G14	Sleep Disorders
			G15	Experiencing difficulty breathing or rapid breathing in later stages.
			G16	Red spots on body

Based on table 2. knowledge base, this research focuses on two types of malaria, namely tertiana and tropical, with 16 (sixteen) disease symptoms, each given the code G01, G02 to G16. For disease symptoms G02 and G04 are found in both malaria diseases, both tertiana and tropica.

3.2. Disease Rule Based on Forward Chaining Rule

The purpose of rule formation is to implement forward chaining rules in diagnosing diseases. The forward chaining rule follows the (IF-THEN) rule. This implements knowledge representation with production rules as rules in the form of (IF-THEN) where the initial part is for the premise situation (IF prefixed statement) and the action is the part that states a certain action where the premise is true (THEN prefixed statement). For the disease malaria tertiana follows the rule:

IF G01 AND G02 AND G03 AND G04 AND G05 AND G06 AND G07 AND G08 AND G15 THEN MTE1.

Tropical malaria follows the rules:

IF G01 AND G02 AND G04 AND G09 AND G10 AND G11 AND G12 AND G13 AND G14 AND G15 AND G16 THEN MT02.

The advantage of a decision tree is that it can be understood by human experts and can be directly converted into production rules. When used to handle a particular case, a decision tree not only provides a solution to the case, but also states the reasoning behind the choice [31][32]. Knowledge representation is also made in the form of a tree diagram. The tree diagram produces a conclusion or recommendation that if the user answers "No" the tree will go to the right branch shown in Figure 3.

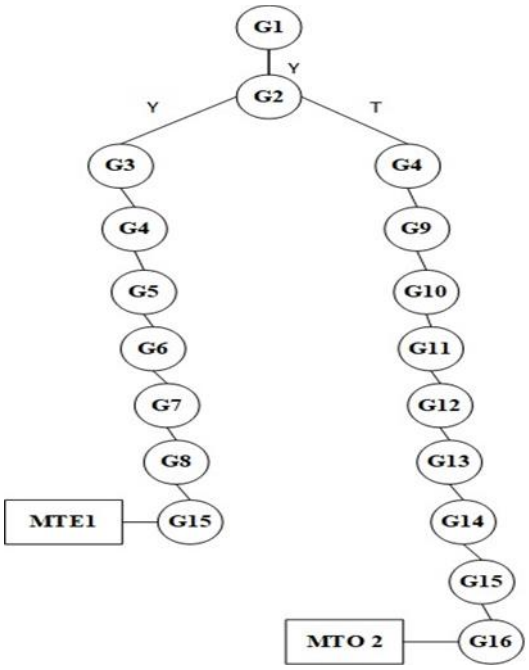

Fig 3. Decision tree

3.3. Determining the MB and MD Weight Values on Certainty Factor Rules

To get the MB value which is the level of confidence and MD, which is the level of disbelief, the knowledge of the expert is very important. The following table relationship for symptoms against MB and MD values from experts in table 3.

Table 3. MB and MD weight values

Knowledge Base						
Code Knowledge	**Code Disease**	**Disease Name**	**Code Symptom**	**Symptom Name**	**MB**	**MD**
1	MTE1	Tertian Malaria	G01	Live in an endemic area	0.8	0.2
			G02	Severe shivering when body temperature rises during a fever attack.	1	0.1
			G03	Severe headache and severe pain.	0.8	0.1
			G04	Feeling tired and weak during a fever attack or afterward.	0.6	0.1
			G05	Muscle and Joint Pain	0.6	0.1
			G06	After the fever phase, sufferers often experience excessive sweating which is very annoying.	0.8	0.1
			G07	Anemia: which can be seen from pale skin	0.6	0.2

			G08	Fever appears in a three-day cycle, namely every 48 hours (first day fever, second day no fever, third day fever returns).	1	0
			G09	Often have difficulty concentrating or are confused during fever attacks.	0.6	0.1
2	MTO2	Tropical Malaria	G10	Fever can appear without a specific cycle and fever attacks can be more frequent.	1	0.1
			G02	Severe shivering when body temperature rises during a fever attack.	1	0.1
			G11	Severe headaches such as migraines are common.	1	0.2
			G12	Symptoms of nausea and vomiting are often accompanied by fever	0.8	0.1
			G04	Feeling very weak and tired during and after a fever attack.	0.6	0.1
			G13	Weight Loss: Loss of appetite and vomiting can cause weight loss.	0.8	0.2
			G14	Sleep Disorders	0.6	0.2
			G15	Experiencing difficulty breathing or rapid breathing in later stages.	0.6	0.2
			G16	Red spots on body	0.8	0.2

3.4. Analysis Results

The results of this analysis are taken from one of the patients that we will detail how to optimize the combination of Forward Chaining and Certainty Factor methods for early diagnosis of tertiana and tropical malaria based on 5 symptoms namely G02, G03, G0, G08, and G14 which are displayed in table 4:

Table 4. Determining MB and MD Weight Values

Kode Symptom	Selected Symptom	MB	MD
G02	Severe shivering when body temperature rises during a fever attack.	1	0.1
G03	Severe headache and severe pain.	0.8	0.1
G06	After the fever phase, sufferers often experience excessive sweating which is very annoying.	0.8	0.1
G08	Fever appears in a three-day cycle, namely every 48 hours (first day fever, second day no fever, third day fever returns).	1	0
G14	Sleep Disorders	0.6	0.2

The results of the analysis using the Certainty Factor method are as follows:

1. **Disease** 1 : Tertian Malaria

Symptom 1 : (G02) Severe shivering when body temperature rises during a fever attack.

Old MB : 0
Old MD : 0
New MB : 1
New MD : 0.1
Temporary MB : 1
Temporary MD : 0.1

Symptom 2 : (G03) Severe headache and severe pain
Old MB : 1
Old MD : 0.1
New MB : 0.8
New MD : 0.1
Temporary MB : Old MB + (New MB * (1 - Old MB))
: 1 + (0.8 * (1 – 1))
: 1
Temporary MD : Old MD + (New MD * (1 - Old MD))
: 0.1 + (0.1 * (1 - 0.1))

: 0.19

Symptom 3 : (G06) After the fever phase, sufferers often experience excessive sweating which is very annoying..

Old MB : 1
Old MD : 0.19
New MB : 0.8
New MD : 0.1
Temporary MB : Old MB + (New MB * (1 - Old MB))
: 1 + (0.8 * (1 – 1))
: 1
Temporary MD : Old MD + (New MD * (1 - Old MD))
: 0.19 + (0.1 * (1 - 0.19))
: 0.271

Symptom 4 : (G08) Fever appears in a three-day cycle, namely every 48 hours (first day fever, second day no fever, third day fever returns).

Old MB : 1
Old MD : 0.271
New MB : 1
New MD : 0
Temporary MB : Old MB + (New MB * (1 - Old MB))
: 1 + (1 * (1 – 1))
: 1
Temporary MD : Old MD + (New MD * (1 - Old MD))
: 0.271 + (0 * (1 - 0.271))
: 0.271
CF : Temporary MB – Temporary MD
: 1 – 0.271
: 0.729

CF : 0.729 * 100%
: 72,9% **[MTE1]**

1. Disease 2 : Tropical Malaria

Symptom 5 : (G14) Sleep Disorders

Old MB : 0
Old MD : 0
New MB : 0.6
New MD : 0.2
Temporary MB : 0. 6
Temporary MD : 0.2
CF : Temporary MB – Temporary MD
: 0.6 – 0.2
: 0.4

CF : 0.4 * 100%
: 40% **[MTO2]**

3.5. Accuracy Test Results

The results of the accuracy test using 50 patient samples at the TWANO Health Center by matching the symptoms experienced to produce a diagnosis of malaria tertiana or tropical malaria following the percentage table of manual calculations and expert diagnosis results in table 5.

Table 5. Hasil Uji Akurasi

No. Patient	Symptom	Percentage Manual Calculation		Expert Diagnosis Result		Accuracy
		Tertiana malaria %	Tropical malaria %	Tertiana malaria %	Tropical malaria %	
1	G02, G03, G06, G08, G14	72,9	40	√	-	appropriate
2	G04, G05, G06, G14, G15	69,7	51,2	√	-	appropriate
9	G02, G10, G11, G12, G15	90	40,8	√	-	appropriate
12	G10, G11	0	72	-	√	appropriate

15	G01, G09, G10, G11	64	72	-	√	appropriate
29	G01, G02, G03, G05	58,3	90	-	√	appropriate
32	G02, G06, G12, G13, G14	81	51, 8	√	-	appropriate
39	G01, G03, G09	63,2	0	√	-	appropriate
42	G01, G10, G12, G13	60	65	√	0	appropriate
50	G01, G03, G06, G08	64,1	0	√	-	appropriate

Calculate system accuracy using the formula (C. Sammut and G. I. Webb, "Encyclopedia of machine learning and data mining.

Accuracy = (correcly classified objects/ total number of objects) * 100%

Accuracy = (45 / 50) x 100% = 90%

4. Conclusion

Optimization of the combination of forward chaining and certainty factor methods in the early diagnosis of malaria tertiana and tropical diseases obtained the results of the selection of symptoms tested by patients obtained an early diagnosis of Tropical Malaria by 40% and Tertiana Malaria by 72.9%. However, the higher percentage results are used as recommendations for diagnosis results, namely Malaria Tertiana. for accuracy testing of the percentage of manual calculations and expert diagnosis results on 50 patient samples, 45 patients were found to match manual and expert calculations and 5 patients who did not match between manual and expert calculations. so that the accuracy rate on optimizing the combination of forward chaining and certainty factor methods is 90%.

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