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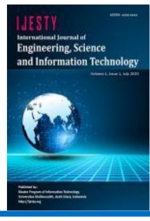

Expert System for Diagnosing Dengue Fever with Comparison of Naïve Bayes and Dempster Shafer Methods

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Abstract

An expert system for diagnosing dengue fever (DF) using a comparison of the Naive Bayes and Dempster Shafer methods aims to provide a solution to assist medical personnel in diagnosing this disease. Dengue fever is a disease caused by the dengue virus infection through the bite of Aedes mosquitoes. It has symptoms similar to other diseases and requires rapid and accurate diagnosis. The Naive Bayes and Dempster Shafer methods were chosen because both have different approaches to handling uncertainty and imprecise information. The Naive Bayes method is a probability-based classification that assumes independence between features. Meanwhile, Dempster Shafer is an approach to handling uncertainty. Therefore, comparing Naive Bayes and Dempster Shafer allows for classification with structured and fairly straightforward data, offering accuracy and flexibility in dealing with uncertainty. Applying this expert system with these methods can help in the faster and more accurate diagnosis of DF and provide better recommendations in situations where the available data is incomplete or ambiguous. From the test data calculations, the two methods show that the Naive Bayes method has a higher percentage value of 93%, while Dempster Shafer has 86%.

Keywords: *Expert System, Diagnosis, Comparison, Naive Bayes, Dempster Shafer.*

1. Introduction

The application of computer science is increasingly expanding into various fields, such as geography, agriculture, tourism, medicine, and others. Along with the rapid development of technology and information, it has positively impacted the healthcare sector, particularly in medicine. The use of technology in healthcare aims to improve health services for better outcomes. A doctor's application of healthcare technology can be seen in the devices used to examine a patient's health. Patients can also benefit from healthcare technology through a system that provides early information about their health condition. A system is any entity consisting of objects, elements, or components that are related and interconnected with one another so that these elements form a unified process or data processing with a specific purpose [1].

Public health issues today are numerous, with various diseases spreading, such as dengue fever (DF). DF is an acute disease caused by the dengue virus infection, which leads to bleeding that can cause shock and death. One of the four virus serotypes in the *Flavivirus* genus, which belongs to the *Flaviviridae* family, causes this disease. Each serotype is so distinct that there is no cross-protection, and outbreaks caused by one serotype (hyperendemicity) can occur. The Aedes aegypti and Aedes albopictus mosquitoes are how the virus enters the human body. Therefore, understanding the causes of dengue fever, how it spreads, and how to prevent it is crucial to halting the spread of this disease in the community [2].

Due to the lack of patient knowledge about the symptoms of dengue fever, the symptoms are not always addressed promptly and appropriately. Suppose dengue fever detection is still performed using conventional methods. In that case, it will take a long time, causing many patients to wait to consult or see a doctor, which also incurs relatively high costs. An expert doctor is also an ordinary human with memory, stress, and fatigue limitations. Due to the large number of patients that need to be managed, treating dengue fever patients can become more challenging. One solution to the above problem is an expert system. Doctors can utilize this system by applying their knowledge and expertise [3].

Based on previous research conducted by Nurdin, Erni Susanti, Hafizh Al-Kausar Aidilof, and Dadang Priyanto (2022) on the comparison of the Naive Bayes and Dempster Shafer methods in an Expert System for Early Diagnosis of Covid-19, the results showed that both the Naive Bayes and Dempster Shafer methods can be applied to an expert system for early Covid-19 diagnosis. From the system testing results, the Naive Bayes method demonstrated better accuracy compared to the Dempster Shafer method [4] [5] [6].

2. Literature Review

2.1. Expert System

An expert system is a branch of AI (Artificial Intelligence) that creates an extension for knowledge specialization to solve problems a Human Expert faces. A Human Expert is highly skilled in a specific field of knowledge, meaning the expert faces issues that others cannot efficiently solve. When expert systems were first developed around the 1970s, they consisted only of knowledge. However, today, the term "expert system" is used for various systems that employ expert system technology. This expert system technology includes expert system languages, programs, and hardware designed to assist in developing and creating expert systems [7].

2.2. Dengue Fever (DF)

Dengue Fever (DF) or Dengue Hemorrhagic Fever (DHF) is a disease caused by the dengue virus, transmitted through the bites of *Aedes aegypti* and *Aedes albopictus* mosquitoes. Dengue Fever (DF) is an infectious disease caused by the dengue virus, with clinical manifestations including fever for 2-7 days, muscle and/or joint pain accompanied by leukopenia, rash, lymphadenopathy, thrombocytopenia, and hemorrhagic diathesis [8] [9] [10].

Dengue Fever (DF) is an infectious disease caused by the dengue virus. It is a significant public health problem in Indonesia due to its high prevalence and expanding spread. Dengue Fever (DF), also known as Dengue Hemorrhagic Fever (DHF), was first reported in Indonesia in 1968. Until now, DF remains one of the significant health problems in Indonesia because of its high prevalence and increasing spread. Outbreaks (Extraordinary Events) of DF occur almost every year in several provinces, with significant outbreaks occurring in 1998 and 2004, when the number of cases reached 79,480, with a death toll of 800 people.

2.3. Naïve Bayes

Naïve Bayes was first introduced by the English scientist Thomas Bayes, known as Bayes' Theorem, which refers to predicting the future based on actions taken in the present. This Bayes' Theorem was then combined with "Naïve," which refers to the assumption that attributes are conditionally independent [11] [12]. Before the classification algorithm was developed in earlier studies, the Bayesian system, often called the Naïve Bayes Classifier, was already in place. Using the Naïve Bayes Classifier can achieve a relatively high level of accuracy with a simple calculation model, making it suitable for analysis on large databases [13] [14].

Step One

Find the value of Prior Probability. The calculation of prior is the process of determining the Likelihood of an event before a case about all cases, which is used as test data [15]. This can be calculated using the following equation:

P(h) = ……………………………..…………………………………………………………………(1)

Explanation:

P(h) = Probability of an event occurring for a case relative to all the cases that have ever happened.

Step Two

Find the value of Likelihood. Likelihood is the process of calculating the Probability of the appearance of a symptom in a case, where the symptom can either be true or false as part of the case. This can be calculated using the following equation:

....……………………..……(2)

Explanation:

P(e|h) = Probability of a symptom occurring in a case.

P(e h) = The number of cases where a symptom and a case co-occur.

P(h) = The total number of occurrences of a case.

Step Three

Find the value of Posterior. Posterior is the final Probability, which can be calculated by multiplying the Prior value of a case by the Likelihood value of each symptom in each case, as experienced by the patient. The equation for this is:

P(h|e) = P(h).P P ………………………………………………………….…………………………………(3)

2.4. Dempster-Shafer

The Dempster-Shafer theory was first introduced by Arthur P. Dempster and Glenn Shafer [16] [17]. Dempster-Shafer is a mathematical theory that aims to prove, based on belief functions and plausible reasoning, which combines pieces of separate information (evidence) to calculate the Probability of an event. Belief (Bel**)** is a measure of the strength (evidence) in supporting a set of propositions [18]. A value of 0 indicates that there is no evidence, while a value of 1 means the presence of Plausibility (P1). Plausibility can be written as follows:

P1(X) = 1-Bel (X) ....(4)

According to Giarratano and Riley in the study (Gustri Wahyuni & Prijodiprojo, 2013), the Belief function can be formulated and expressed in the following equation:

Explanation
Bel (X) = Belief (X)
m(X) = Mass function from (X)
formula *dempster shafer* :

$$m3(Z) = \frac{\sum_{X \cap Y = Z} m1(X).m2(Y)}{1 - \sum_{X \cap Y = \emptyset} m1(X).m2(Y)}$$

Explanation
m3(Z) = *Mass Function* which is the value of the intersection of m1 and m2 divided by 1 minus the empty intersection of m1 and m2.
m1(X) = *Mass Function*, which is a disease with symptom A
m1(X) = *Mass Function* is a disease with symptom B

Plausibility also has a value ranging from 0 to 1. If one is sure about -s, it can be said that Bel(-s) = 1 and Pl(-s) = 0. Plausibility will reduce the level of confidence in the evidence. In Dempster-Shafer's theory, we encounter the concept of a frame of discernment, denoted by θ, and a mass function, denoted by m. This frame represents the universe of discourse of a set of hypotheses. Let us assume:

θ = {D01, D02, D03, D04}

With:
D01 = Dengue I Dengue (Dengue fever without severity)
D02 = Dengue II Dengue (Dengue fever with severe symptoms)
D03 = Dengue III Dengue (Dengue fever with shock)
D04 = Dengue IV Dengue (Dengue fever with organ failure).

3. Research Methods

This research is conducted at Arun Hospital Lhokseumawe. This location was chosen to facilitate data collection and reference gathering for the development of the system, ensuring that the research progresses smoothly. The research period is from January 2024 to June 2024. The steps of the research are as follows:

1. Literature Study
   The literature study is conducted to obtain theories relevant to the research problem and achieve the writing objectives. The author uses scientific journals, books, articles, and references from the final theses as materials for the literature study and as supporting foundations for the research.
2. Data Collection
   The author obtains data from Arun Hospital Lhokseumawe. The researcher interviews Dr Zulfahmi, a specialist doctor handling dengue fever (DBD) cases and data in the form of patient medical records. These medical records are then analyzed to obtain specific data and recorded in an Excel spreadsheet for more straightforward data processing. One hundred cases were taken, and 100 patients were diagnosed as positive for dengue fever.
3. System Design
   System design determines the processes and data required by the new system. System design can be defined as the depiction, planning, and sketching of a system. The goal is to produce software products that meet the user's needs.
4. Implementation
   The implementation phase involves testing the use of the application program. This process will include writing code in various programming languages, testing each component, and integrating them into a functioning system.
5. System Testing
   The system testing phase evaluates the software or system to determine if it functions correctly according to the established requirements or specifications. The goal is to find errors or defects in the software or system and ensure they are fixed before the final product is released.

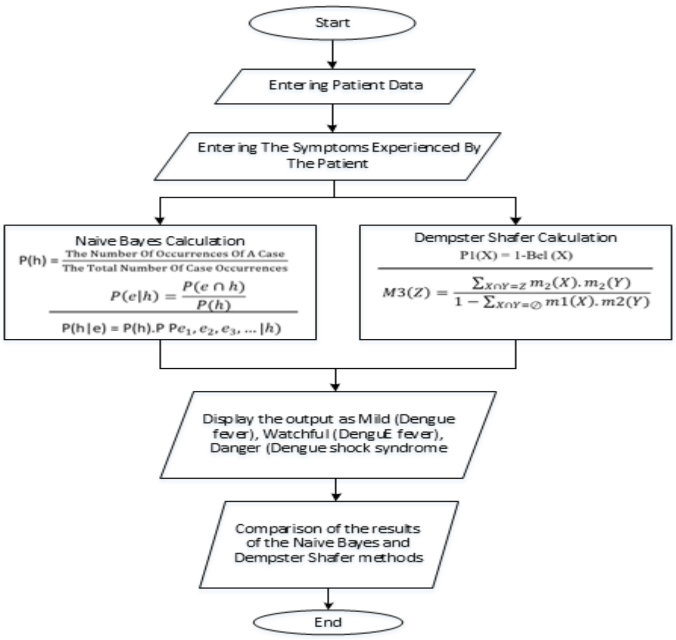

Fig 1. System Schematic

4. Results and Discussion

The author conducts the system analysis to identify and determine each process step that needs to be followed to solve the existing problems. This system analysis aims to ensure that each stage in the system process runs accurately and according to the intended objectives in the expert system for diagnosing dengue fever by comparing the Naive Bayes and Dempster Shafer methods.

1. Data on Diagnosis Types and Symptoms
   The table below contains symptoms associated with cases of each type categorized under mental disorders.

Table 1. Types of Diagnosis and Symptoms

Type of Diagnosis	Symptoms
D01	High fever reaching 38 degrees Celsius for 1 to 3 days
	Headache
	Muscle pain, joint pain behind the eyes, and sore throat
	Nausea and vomiting
	Red rash
	Dizziness, fatigue, and weakness
	Loss of appetite
D02	Muscle pain, joint pain behind the eyes, and sore throat
	Nausea and vomiting
	Bleeding (Nosebleed, gums, red spots on the skin)
	Dizziness, fatigue, and weakness
	Abdominal pain
	Organ dysfunction (liver and kidney)
	Shock (low blood pressure, rapid heartbeat, cold and clammy skin)
D03	Bleeding (Nosebleed, gums, red spots on the skin)
	Dizziness, fatigue, and weakness
	Organ dysfunction (liver and kidney)
	Shock (low blood pressure, rapid heartbeat, cold and clammy skin)
	Breathing difficulties
	Drastic decrease in urine output
D04	Bleeding (Nosebleed, gums, red spots on the skin)
	Dizziness, fatigue, and weakness
	Organ dysfunction (liver and kidney)
	Loss of consciousness
	Shock (low blood pressure, rapid heartbeat, cold and clammy skin)
	Decreased platelet count
	Drastic decrease in urine output

2. Naïve Bayes Calculation
   For the calculation process of the Naïve Bayes method, the data required is as follows:
   a. Diagnosis
      Diagnosis is a variable divided into four categories: Dengue I, Dengue II, Dengue III, and Dengue IV.

Table 2. Dengue Diagnosis

symptom code	symptom
D0	Dengue Level I
D02	Dengue Level II
D03	Dengue Level III
D04	Dengue Level IV

b. Symptoms

The symptoms are divided into several parts, as follows:

Table 3. Symptoms

Symptoms code	Symptoms
G01	High fever reaching 38°C for 1 to 3 days
G02	Headache
G03	Muscle pain, joint pain, pain behind the eyes, and sore throat
G04	Nausea and vomiting
G05	Red rash
G06	Bleeding (nosebleeds, gums, red spots on the skin, gastrointestinal bleeding)
G07	Dizziness, fatigue, and weakness
G08	Loss of appetite
G09	Plasma leakage
G10	Abdominal pain
G11	Organ dysfunction (liver and kidneys)
G12	Loss of consciousness
G13	Shock (low blood pressure, rapid heart rate, cold and clammy skin)
G14	Difficulty breathing
G15	Decreased platelet count
G16	Drastic decrease in urine output

c. Test data

Table 4. Example of Naive Bayes Case

No.	Symptom code																Diagnosis
	G01	G02	G03	G04	G05	G06	G07	G08	G09	G10	G11	G12	G13	G14	G15	G16	
1	✓		✓	✓		✓	✓			✓	✓		✓				D02

The steps for performing manual calculations using the Naïve Bayes method are as follows:

Test data 1 (D01, D03, D04, D06, D07, D10, D11, and D13)

- Prior probability value

P(h) =

- Likelihood value

P(e|h) =

- Posterior value

P(h|e) = P(h).P P

From the above calculation, it can be concluded that the highest probability value is found in D02 (Dengue Level II). Therefore, it is determined that the patient is diagnosed with Dengue Fever Level II, with symptoms such as a high fever reaching 38°C for 1 to 3 days, muscle pain, joint pain, pain behind the eyes, and sore throat, nausea and vomiting, bleeding (nosebleeds, gum bleeding, red spots on the skin, gastrointestinal bleeding), dizziness, fatigue, and weakness, abdominal pain, organ dysfunction (liver and kidney), and shock (low blood pressure, rapid heartbeat, cold and clammy skin).

3. Dempster Shafer calculation

In this phase, the researcher will perform manual calculations using the Dempster-Shafer method to determine the certainty of a case. The following steps are used for manual calculations using the Dempster-Shafer method:

a. Diagnosis

Diagnosis is a variable divided into four categories: Dengue I, Dengue II, Dengue III, and Dengue IV.

Table 5. Dengue Diagnosis

symptom code	symptom
D0	Dengue Level I
D02	Dengue Level II
D03	Dengue Level III
D04	Dengue Level IV

b. Symptoms

The symptoms in the dempster shafer data are divided into several parts, as shown in the following table:

Table 6. Symptoms

Symptom code	Symptoms				Confidence value	Uncertainty value
	D01	D02	D03	D04		
G01	0,6	0,7			0,65	0,35
G02	0,5				0,5	0,5
G03	0,6				0,6	0,4
G04	0,5	0,7			0,6	0,4
G05	0,5				0,5	0,5
G06		1	1	1	1	0
G07	0,5	0,7	0,8	0,9	0,72	0,28
G08	0,5				0,5	0,5
G09				1	1	0
G10		0,6			0,6	0,4
G11		1	1	1	1	0
G12				1	1	0
G13		1	1	1	1	0
G14			1		1	0
G15				1	1	0
G16			1	1	1	0

- Uncertainty value
  P1(X) = 1-Bel (X)

  The Dempster Shafer formula is as follows:

Table 7. Example of Dempster Shafer Case

No.	Symptoms Code																Diagnosis
	G01	G02	G03	G04	G05	G06	G07	G08	G09	G10	G11	G12	G13	G14	G15	G16	
1	✓		✓	✓		✓	✓			✓	✓		✓				D02

Steps for performing manual calculations using the Dempster-Shafer method:
Test data (D01, D03, D04, D06, D07, D10, D11, and D13)

The calculation above shows the highest probability value in D02 (Dengue Level II). Thus, it is concluded that the patient has Dengue Fever Level II with symptoms such as high fever (38°C for 1-3 days), muscle and joint pain, pain behind the eyes, sore throat, nausea, vomiting, bleeding (nosebleeds, gum bleeding, red spots on the skin, gastrointestinal bleeding), dizziness, fatigue, weakness, abdominal pain, organ dysfunction (liver and kidney), and shock (low blood pressure, rapid heartbeat, cold and clammy skin).

4. Testing of Both Naïve Bayes and Dempster Shafer Methods
   a. Testing test data on the Naïve Bayes method

Table 8. Naïve Bayes Test Data

No.	Symptoms	Naïve Bayes	Expert Diagnosis
1	G01, G03, G04, G06, G07, G10, G11, and G013	D02 (0,0361)	D02
2	G06, G07, G11, G13, G14, and G16	D02 (0,0281)	D02
3	G06, G07, G11, G13, G14, and G16	D03 (0,363)	D03
4	G02, G03, G04, G06, G07, G10, G11, and G13	D02 (0,0281)	D02
5	G01, G03, G06, G07, G10, G11, and G13	D02 (0,0385)	D02
6	G06, G07, G08, G11, G12, G13, G15, and G16	D04 (0,0082)	D04
7	G06, G07, G11, G13, G14, and G16	D03 (0,363)	D03
8	G06, G07, G11, G13, G14, and G16	D03 (0,363)	D03

9	G01, G06, G07, G11, G13, G14, and G016	D02 (0,0484)	D02
10	G01, G03, G04, G05, G06, and G08	D01 (0,0352)	D02
11	G01, G02, G03, G04, G05, G07, and G08	D01 (0,1504)	D02
12	G03, G04, G06, G07, G10, G11, and G013	D02 (0,2386)	D02
13	G06, G07, G11, G12, G13, G15, and G16	D04 (0,0741))	D04
14	G03, G04, G06, G07, G10, G11, and G013	D02 (0,2386)	D02
15	G06, G07, G11, G13, G14, and G16	D03 (0,363)	D03
16	G01, G03, G04, G05, G06, G07, G08, and G10	D01 (0,0033)	D01
17	G01, G02, G03, G04, G05, G07, and G08	D01 (0,1504)	D01
18	G01, G02, G03, G04, G05, G07, and G08	D01 (0,1504)	D01
19	G03, G04, G06, G07, G10, G11, and G013	D02 (0,2386)	D02
20	G01, G02, G03, G04, G05, G07, and G08	D01 (0,1504)	D01
21	G01, G02, G03, G04, G05, G07, and G08	D01 (0,1504)	D01
22	G01, G02, G03, G04, G05, G07, and G08	D01 (0,1504)	D01
23	G03, G04, G06, G07, G10, G11, and G013	D02 (0,2386)	D02
24	G01, G02, G03, G04, G05, G07, and G08	D01 (0,1504)	D01
25	G01, G02, G03, G04, G05, G07, and G08	D01 (0,1504)	D01
26	G01, G02, G03, G04, G05, G07, and G08	D01 (0,1504)	D01
27	G01, G02, G03, G04, G05, G07, and G08	D01 (0,1504)	D01
28	G01, G03, G05, G06, G07, G08, G09, G12, G14, and G16	D01 (0,0982)	D01
29	G01, G04, G05, G06, G11, and G014	D03 (0,0001)	D03
30	G03, G04, G06, G07, G10, G11, and G13	D02 (0,2386)	D02

From the test data in Table 4.10, the results of the manual calculation using Naïve Bayes show that 11 patients are diagnosed with Dengue Fever Level I (D01), 10 patients with Dengue Fever Level II (D02), five patients with Dengue Fever Level III (D03), and two patients with Dengue Fever Level IV (D04). Based on the calculation above, the accuracy of the expert system using the Naïve Bayes method is 93%.

5. Testing of Test Data on the Dempster Shafer Method

Table 9. Dempster Shafer Test Data

No.	Symptoms	Dempster Shafer	Expert Diagnosis
1	G01, G03, G04, G06, G07, G10, G11, and G13	D02 (0.944)	D01
2	G06, G07, G11, G13, G14, and G16	D02 (0.84)	D01
3	G06, G07, G11, G13, G14, and G16	D03 (1)	D03
4	G02, G03, G04, G06, G07, G10, G11, and G13	D02 (0.84)	D01
5	G01, G03, G06, G07, G10, G11, and G13	D02 (0.86)	D03
6	G06, G07, G08, G11, G12, G13, G15, and G16	D04 (1)	D04
7	G06, G07, G11, G13, G14, and G16	D03 (1)	D03
8	G06, G07, G11, G13, G14, and G16	D03 (1)	D02
9	G01, G06, G07, G11, G13, G14, and G016	D03 (1)	D03
10	G01, G03, G04, G05, G06, and G08	D02 (0,86)	D02
11	G01, G02, G03, G04, G05, G07, and G08	D01 (0,95)	D01
12	G03, G04, G06, G07, G10, G11, and G013	D02 (0,84)	D02

13	G06, G07, G11, G12, G13, G15, and G16	D04 (1)	D04
14	G03, G04, G06, G07, G10, G11, and G013	D02 (0,84)	D02
15	G06, G07, G11, G13, G14, and G16	D03 (1)	D02
16	G01, G03, G04, G05, G06, G07, G08, and G10	D02(0,944)	D02
17	G01, G02, G03, G04, G05, G07, and G08	D01 (0,95)	D02
18	G01, G02, G03, G04, G05, G07, and G08	D01 (0,95)	D01
19	G03, G04, G06, G07, G10, G11, and G013	D02 (0,84)	D02
20	G01, G02, G03, G04, G05, G07, and G08	D01 (0,95)	D01
21	G01, G02, G03, G04, G05, G07, and G08	D01 (0,95)	D01
22	G01, G02, G03, G04, G05, G07, and G08	D01 (0,95)	D01
23	G03, G04, G06, G07, G10, G11, and G013	D02 (0,84)	D02
24	G01, G02, G03, G04, G05, G07, and G08	D01 (0,95)	D01
25	G01, G02, G03, G04, G05, G07, and G08	D01 (0,95)	D01
26	G01, G02, G03, G04, G05, G07, and G08	D01 (0,95)	D01
27	G01, G02, G03, G04, G05, G07, and G08	D01 (0,95)	D01
28	G01, G03, G05, G06, G07, G08, G09, G12, G14, and G16	D01(0,944)	D02
29	G01, G04, G05, G06, G11, and G014	D03 (1)	D03
30	G03, G04, G06, G07, G10, G11, and G13	D02 (0,84)	D02

Based on the test data in Table 4.11, the results of the manual calculation using Dempster Shafer show that nine patients were diagnosed with Dengue Fever Level I (D01), 11 patients with Dengue Fever Level II (D02), four patients with Dengue Fever Level III (D03), and two patients with Dengue Fever Level IV (D04). Based on the calculation above, the accuracy of the expert system using the Dempster Shafer method is 86%.

The results of each calculation above show that the highest accuracy is found in the manual calculation of Naïve Bayes. The calculation of test data for both methods indicates that the Naïve Bayes method has a higher percentage accuracy of 93%, compared to the Dempster Shafer method, which is 86%.

5. Conclusion

Based on the research results, the researcher can conclude the following about the expert system for diagnosing Dengue Hemorrhagic Fever (DHF) using the comparison methods of Naive Bayes and Dempster Shafer:

1. The researcher also concludes that medical personnel can diagnose and recommend treatment more quickly, enabling them to provide initial handling. The decisions become more information-based with the system providing more profound analysis and considering various possibilities.
2. The variables in this expert system include four categories: Dengue Level I (D01), Dengue Level II (D02), Dengue Level III (D03), and Dengue Level IV (D04). There are 16 symptoms, including high fever reaching 38°C for 1 to 3 days, headaches, pain (muscle, joints, behind the eyes, and throat), nausea and vomiting, rash, bleeding (nosebleeds, gums, red spots on the skin, gastrointestinal bleeding), dizziness, fatigue, weakness, loss of appetite, plasma leakage, abdominal pain, organ dysfunction (liver and kidney), loss of consciousness, shock, difficulty breathing, platelet decrease, and a drastic decrease in urine output.
3. Regarding accuracy in comparing the Naive Bayes and Dempster Shafer methods, the results show that Naive Bayes has an accuracy of 93% and Dempster Shafer 86%, based on the calculation from 30 test data used.
4. The symptoms that most frequently appear in DHF based on the 30 test data collected by the researcher are high fever, severe headaches, muscle pain, skin rash, and bleeding.
5. From the test data calculations performed by the researcher, it is found that using the Naive Bayes method has a higher percentage value, 93%, compared to the Dempster Shafer method, which is 86%.

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