Development of an Intelligent System for Early Diagnosis of Diseases in Toddlers Using Forward Chaining and Dempster-shafer Integration

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Abstract— Toddlerhood is an important period in a child's growth and development. In this period children will be vulnerable to disease. There are several types of diseases that range in toddlers such as diarrhea, pneumonia, malaria, etc. The problems faced are the limited access and quality of health services in some areas where health costs are still relatively high, the availability of health workers is also not always available, and the lack of knowledge related to toddler health. So, a system is needed that can provide knowledge and first aid information related to the health of toddlers which is expected to help in reducing the mortality rate of toddlers, especially for the types of diseases that can cause death such as diarrhea, pneumonia and malaria. The methods used in this research are Forward Chaining and Dempster-shafer. The result of this research is an intelligent system that applies forward chaining and dempster-shafer methods to diagnose early diseases in toddlers. The test results carried out in this research show an accuracy value of 90% of 10 tests. The results of Blackbox and usability testing conducted also show that the developed system is as expected and feasible to use.

Keywords— Toddler, Intelligent System, Early Diagnosis, Forward Chaining, Dempster-shafer, Toddler Disease

I. INTRODUCTION

Toddlerhood is an important period in child development. In this period children will be vulnerable to disease [1]. here are several types of diseases that range in toddlers such as diarrhea [2], pneumonia [3], ISPA [4], malnutrition [5], stunting [6], malaria [7], skin [8], measles [9], fever [10], flu [11] and others Some diseases are even the cause of death of children under five [12] such as diarrhea, pnemunia, and malaria with the highest mortality rate of 29% of the total mortality rate of children under five globally The under-five mortality rate in Indonesia is quite high, based on data obtained from the Central Statistics Agency (BPS) in 2020, the under-five mortality rate reached 19-20 deaths every 1000 births [14]. Therefore, several efforts are needed to reduce the death rate. One way that can be done is to maintain early childhood health [15].

In maintaining the health of toddlers there are several challenges or **problems** faced, namely the limited access and quality of health services in some areas where health costs are still relatively high, the availability of health workers is also not always available, and the lack of knowledge related to the health of toddlers. So, it takes a system that can provide knowledge and first aid information related to the health of toddlers which is expected to help in reducing the mortality rate of toddlers, especially for the types of diseases that can cause death such as diarrhea, pneumonia and malaria.

An intelligent system is a system developed to mimic the ability of human thinking in making decisions. This system works by using the data that has been collected to solve a problem. There are several methods that can be used in developing intelligent systems including forward chaining and dempster-shafer. *Forward chaining* is one of the expert system methods in which this method uses inference rules to draw a conclusion [16]. While *dempster-shafer* is a method that can be used to handle uncertainty in decision making [17], [18], [19].

This research will develop an intelligent system that can be used to diagnose early diarrhea, pneumonia and malaria in toddlers and provide recommendations for the first action against the symptoms experienced by the toddler. This Intelligent System is developed by integrating Forward Chaining and Dempster-shafer. Integration is done by incorporating uncertainty handling from dempster-shafer into the inference process in *Forward Chaining*. This allows the system to consider the level of confidence or uncertainty in the facts given and the inference rules used. It is hoped that the development of this system can help parents or the community in early diagnosis and provide first aid for diarrhea, pneumonia and malaria in toddlers and can reduce the mortality rate of toddlers caused by these diseases.

There are several previous studies related to the development of systems for diagnosing diseases in toddlers such as research by Juadon and Suharjo [20] discussing the development of an expert system used to diagnose diarrheal diseases in children aged 1-6 years using the *Forward Chaining* method. Elmi et al [21] developed an expert system used to diagnose diarrhea in toddlers using the *Forward Chaining* method. Herman et al [22] developed an expert system to diagnose diseases in infants such as diarrhea and malaria using the dempster-shafer method. Safa et al [23] discussed the combination of artificial neural networks with *Dempster-shafer* in diagnosing pneumonia. Purwanti et al [24] developed an application used to determine the level of pneumonia using the *Dempster-shafer* method. Fitri et al [25] discussed the combination of the *Forward Chaining* method with the certaity factor in diagnosing respiratory diseases, one of which is pneumonia. Kuswanto and Dapiokta discussed the application of the forwar chaining method in diagnosing pneumonia. Marusaha et al [27] discussed the diagnosis of malaria using the dempster-shafer method. Winahyu et al [28] discuss the application of intelligent systems in diagnosing diseases caused by mosquito parasites using the demspter-shafer method, one of which is malaria. And there are still other studies such as [29], [30], [31], [32] [33].

However, the difference between previous research and what will be done is that some previous studies discussed only one disease, be it diarrhea, pneumonia or malaria, while the research to be carried out is related to diarrhea, pneumonia and malaria in toddlers and provides knowledge and recommendations for first aid measures. In addition, some previous studies only used one method, either *Forward Chaining* or *Dempster-Shafer*. Whereas this research integrates both methods to provide a system to consider the level of trust or uncertainty in the facts given and the inference rules used. So the state of the art of the research will lie in the integration of the *Forward Chaining* and *Dempster-shafer* methods to diagnose early diarrhea, pneumonia and malaria in toddlers and provide first aid recommendations for these diseases. With this system, it is expected to help reduce the mortality rate in toddlers caused by diarrhea, pneumonia and malaria.

II. METHOD

In the development of an intelligent system for diagnosing toddler diseases, the methods used in this research are *forward chaining* and *dempster-shafer*. *Forward chaining* is one of the expert system methods in which this method uses inference rules to draw a conclusion [16]. While *dempster-shafer* is a method that can be used to handle uncertainty in decision making [17], [18], [19]. The *forward chaining* method is integrated with *Dempster-Shafer* to allow the system to consider the level of trust or uncertainty in the facts given and the inference rules used. The research stages of developing this intelligent system can be seen in Figure 1.

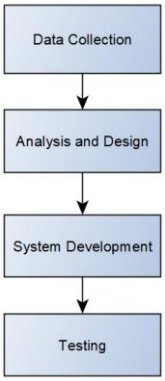

Figure 1. Research Stages

Figure 1 shows the stages of research carried out in this research. In general, the stages carried out start from data collection, analysis and design, system development and testing..

1. Data Collection
   At this stage, data collection on diseases in toddlers and their symptoms is carried out.
2. Analysis and Design
   At this stage, user requirements analysis, system flow design (forward chaining and dempster-shafer) are carried out.
3. System Development
   At this stage, the development of a smart web-based system is carried out.
4. Testing
   At this stage, testing of the developed system is carried out. At this stage testing is carried out using blackbox, usability and also accuracy.

III. RESULT AND DISCUSSION

This study uses disease data along with symptoms of diseases suffered by toddlers such as diarrhea, pneumonia, malaria and others. The disease data can be seen in Table 1.

Table 1. Disease Data

Disease Code	Disease Name
D-0001	Diarrhea
D-0002	Pneumonia
D-0003	Malaria
D-0004	Measles
D-0005	Dengue
D-0006	Influenza
D-0007	Rubella
D-0008	Croup
D-0009	Chicken Pox
D-0010	Bronchitis

Each disease has its own symptoms. The symptoms can be seen in Table 2.

Table 2. Symptom Data

Symptom Code	Symptom Code
S-01	Cough
S-02	Fever
S-03	Frequent and watery bowel movements
S-04	Itching
S-05	Nasal congestion
S-06	Small amount of urine or dark yellow-brown color

Symptom Code	Symptom Code
……	.....
S-38	Loss of appetite
S-39	Flatulence

Table 2 shows the symptom data used in this study. The symptom data is linked to disease data because each disease can have more than one symptom. The example of this data can be seen in Table 3.

Table 3. Disease and Symptom Data

Disease Code	Sympton Code
D-0001	S-03
	S-02
	S-38
	S-39
	S-20
	S-21
D-0002	S-02
	S-01
	S-28
	S-29
……..	……..
D-0010	S-01
	S-25
	S-26

Table 3 shows sample data of diseases and symptoms used in this study. After having this data, rules are made using the forward chaining method. The rule example can be seen in Table 4.

Tabel 4. Rule

Code	Rule
R1	If S-03 and S-02 and S-38 and S-39 and S-20 and S-21 Then D-0001
R2	If S-01 and S-02 and S-28 and S-29 Then D-0002
…….	…….
R10	If S-01 and S-25 and S-26 Then D-0010

Table 4 shows some examples of rules obtained in this study. The next stage is the Demster-shafer stage. This stage begins by giving the weight of each symptom in the disease. The sample data can be seen in Table 5.

Table 5. Wight Data

Disease Code	Sympton Code	Weight
D-0001	S-03	0.8
D-0001	S-02	0.7
D-0001	S-38	0.8
D-0001	S-39	0.7
D-0001	S-20	0.7
D-0001	S-21	0.8
D-0002	S-02	0.7
D-0002	S-01	0.8
D-0002	S-28	0.8
D-0002	S-26	0.8
……..	……..	
D-0010	S-01	0.8
D-0010	S-25	0.6
D-0010	S-26	0.8

After getting the weighting data. The next stage is to examine the symptoms experienced by the patient and then enter the equation used in Dempster-shafer. The equation can be seen in Equation 1.

$$M(A) = \frac{\sum_{B \cap C = A} m1(B).m2(C)}{1 - \sum_{B \cap C = \emptyset} m1(B).m2(C)} \quad (1)$$

The results of these calculations show the results of disease diagnoses obtained based on the selected symptom data. The case example is a patient has symptoms of frequent and watery defecation (S-03), Cough (S-01), Fever (S-02), Loss of Appetite (S-38), Flatulence (S-39), Vomiting (S-20), and Nausea (S-21). From the symptom data, a suitability check is then carried out with the rules owned by forward chaining.

Based on the matching results, there are several possible diseases according to the forward chaining rule, such as diarrhea, pneumonia, influenza, bronchitis, and croup. Furthermore, calculations are carried out using Dempster-Shafer.

a. Diagnosis D-0001 (Diare)

The relevant symptoms for diagnosis D-0001 and their associated mass function (m) values are :

1. Frequent and watery bowel movements (S-03): m(S-03) = 0.8
2. Fever (S-02): m(S-02) = 0.7
3. Loss of Appetite (S-38): m(S-38) = 0.8
4. Flatulence (S-39): m(S-39) = 0.7
5. Vomiting (S-20): m(S-20) = 0.7
6. Nausea (S-21): m(S-21) = 0.8

Calculation Steps for Diagnosis D-0001

1. First combination between S-03 dan S-02: m (S-03 ∩ S-02) ≈ **0.5957**
2. Combination of the above result with symtom S-38: m (S-03 ∩ S-02 ∩ S-38) ≈ **0.5185**
3. Next combination with S-39: m(S-03 ∩ S-02 ∩ S-38 ∩ S-39) ≈ **0.4243**
4. Next combination with S-20: m(S-03 ∩ S-02 ∩ S-38 ∩ S-39 ∩ S-20) ≈ **0.3590**
5. The combination with S-21: m(S-03 ∩ S-02 ∩ S-38 ∩ S-39 ∩ S-20 ∩ S-21) ≈ **0.3293**

b. Diagnosis D-0002 (Pneumonia)

There are 2 relevant symptoms, S-02 and S-01.
m(S-02 ∩ S-01) ≈ **0.5957**

c. Diagnosis D-0002 (Pneumonia)

Diagnosis D-0006 has the same symptoms as D-0002, namely S-02 and S-01. Therefore, the Dempster-shafer calculation will produce the same confidence value which is Final confidence ≈ **0.5957**

d. Diagnosis D-0010

Diagnosis D-0010 has only 1 associated symptom, which is S-01. Thus, the final confidence value for this diagnosis is m(S-01) ≈ **0.8**

e. Diagnosis D-0008

Diagnosis D-0008 also has only 1 associated symptom, which is S-01. Thus, the final confidence value for this diagnosis is m(S-01) ≈ **0.8**

After combining all relevant symptoms, the final result for each diagnosis is as follows:

Diagnosis D-0001: Final confidence ≈ 0.3293
Diagnosis D-0002: Final confidence ≈ 0.5957
Diagnosis D-0006: Final confidence ≈ 0.5957
Diagnosis D-0010: Final confidence ≈ 0.8
Diagnosis D-0008: Final confidence ≈ 0.8

With this value, it can be concluded that Diagnoses D-0010 and D-0008 have the highest confidence level for the given symptoms, followed by Diagnoses D-0002 and D-0006.The calculation process using forward chaining and dempster-shafer is then developed in a website-based system. The appearance of the system can be seen in Figure 2.

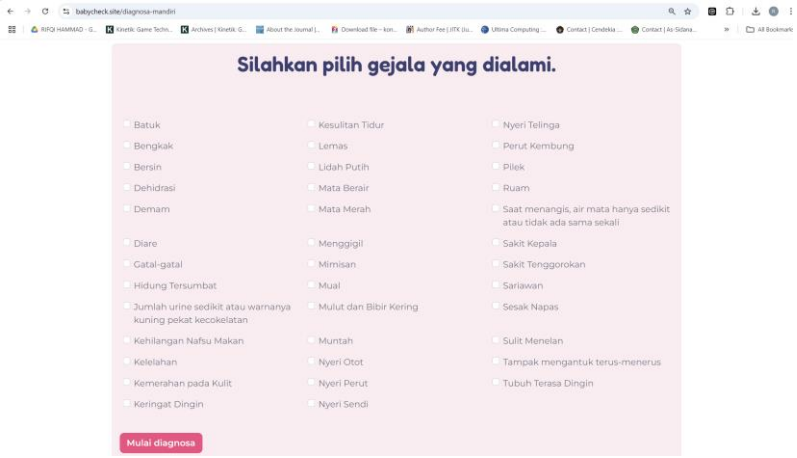

Figure 2. Diagnosis Page

Figure 2 shows the page used for users to select symptoms experienced by toddlers. After the user selects the symptom data, the system will display the diagnosis results based on the data that has been inputted. The example can be seen in Figure 3.

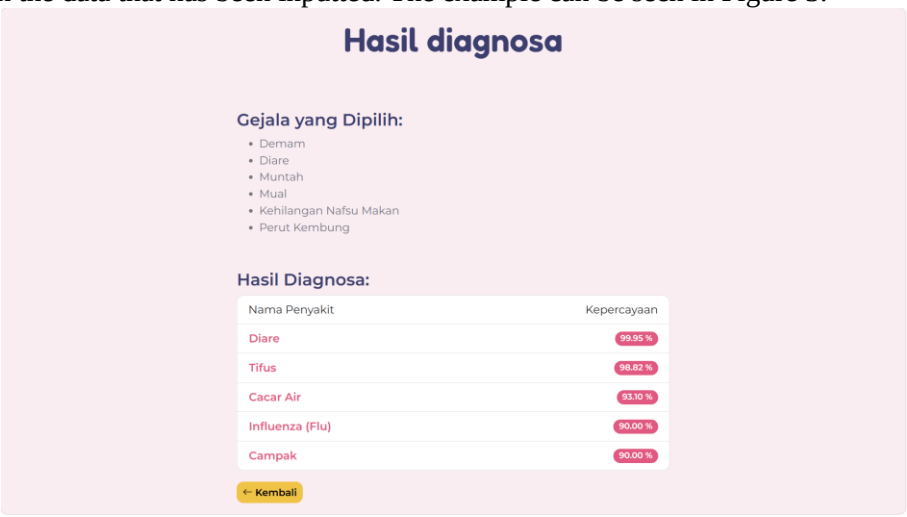

Figure 3. Diagnosis Result Page

Figure 3 shows the diagnosis results based on the selected symptoms. The last stage is testing. Testing is done using blackbox, usability and accuracy. The results of blackbox testing can be seen in Table 6.

Tabel 6. Blackbox Testing

No	Scenario	Expected Results	Description
1	Manage symptom data	Symptom data can be added, modified and deleted	Suitable
2	Manage disease data	Disease data can be added, modified and deleted	Suitable
3	Manage symptom-disease detail data	Disease symptom detail data can be added, modified and deleted	Suitable
4	Self-Diagnosis	The system displays the results of self-diagnosis	Suitable
5	About the Application	The system displays information related to the babychcek application	Suitable
6	Research Team	The system displays information related to the research team	Appropriate
7	Health Articles	The system displays health articles	Suitable

Table 6 shows that the developed system is as expected. The next test uses usability testing. Testing is done using a scale of 1-5. The results of the usability testing can be seen in Table 7.

Tabel 7. Usability Testing

Statements	Average Score
The system interface is easy to understand and allows me to enter symptoms quickly and without difficulty.	4.3
The system provides clear and easy-to-understand diagnosis information, so I feel confident in the results provided.	4.5
The diagnosis process in this system is efficient and fast, allowing me to make early diagnosis decisions without significant time constraints.	4.4
The feature to add or change inputted symptoms is very flexible and makes it easy to update toddler data.	4.2
I find it helpful to have disease information stored in the system.	4.6

Table 7 shows that the results of the usability testing conducted state that the developed system is feasible to use with an overall average value of 4.4 out of 5. Further testing is carried out to determine the level of accuracy possessed by the developed system. The test can be seen in table 8.

Tabel 8. Accuration Testing

No	Scenario	System Result	Expert Result	Description
1	S-03, S-02, S-38, S-39, S-20, S-21	Diarrhea	Diarrhea	Suitable
2	S-02, S-01, S-07	Influenza	Influenza	Suitable
3	S-02, S-01, S-28, S-29	Pneumonia	Pneumonia	Suitable
4	S-02, S-20, S-23, S-14, S-22, S-34, S-33, S-35	Malaria	Malaria	Suitable
5	S-01, S-25, S-26	Bronchitis	Bronchitis	Suitable
6	S-03, S-38, S-39, S-20, S-21	Diarrhea	Diarrhea	Appropriate
7	S-02, S-15, S-16	Rubella	Rubles	Appropriate
8	S-02, S-38, S-39, S-20, S-21	Diarrhea	Malaria	Not compliant
9	S-11, S-01, S-02	Colds	Cold	Appropriate
10	S-02, S-22, S-19	Chicken Pox	Chicken Pox	Appropriate

Table 8 shows that the accuracy rate of the developed system is 90%.

IV. CONCLUSION

The intelligent system for early diagnosis of toddler diseases developed using forward chaining and dempster-shafer gets an accuracy value of 90% from 10 tests. The results of blackbox and usability testing conducted also show that the system developed has been in accordance with what is expected and feasible to use. The suggestions for future research

are the addition of disease data and symptoms along with the addition of algorithms so that the results of this intelligent system become better and more accurate.

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