Examination of an Expert System for Identifying the Singapore Flu Infectious Disease in Young Children the Dempster-Shafer Algorithm

Edy Sarwono Ponco, Zulham Sitorus

Abstract

This research aims to develop an expert system that can detect the contagious Singapore flu in toddlers using the Dempster-Shafer algorithm. Singapore flu, caused by the enterovirus, often affects children, especially toddlers, with varying symptoms, including fever, rash, and oral ulcers. Early detection is crucial to reduce the impact of the spread of this disease. The expert system developed in this research utilises the Dempster-Shafer algorithm to process information and provide decisions based on the input symptom data. The Dempster-Shafer algorithm was chosen for its ability to handle uncertainty and deliver more accurate results in situations where the available information is incomplete or ambiguous. This research implements a computer-based system that can assist medical personnel in diagnosing Hand, Foot, and Mouth Disease (HFMD) by identifying symptoms present in toddler patients, as well as providing appropriate action recommendations based on the diagnosis results. The test results show that this system has high accuracy in detecting Hand, Foot, and Mouth Disease in toddlers, and can serve as an effective tool in improving the speed and accuracy of diagnosis, thereby supporting faster and more precise treatment. Thus, this expert system is expected to make a significant contribution to the prevention and control of Hand, Foot, and Mouth Disease in toddlers.

Keywords: *Singapore, Toddlers, Dempster-Shafer, Algorithm, Disease Detection, Medical Diagnosis*

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Introduction

Infectious diseases, especially those affecting toddlers, are a serious health issue in various countries, including Indonesia. One of the infectious diseases that occurs quite frequently in children is Hand, Foot, and Mouth Disease (HFMD), caused by enteroviruses, particularly coxsackievirus A16 and enterovirus 71. Hand-foot-and-mouth disease (HFMD) or penyakit tangan, kaki, dan mulut is an acute viral infection disease that is usually mild and self-limiting. However, HFMD can cause severe complications in the central nervous system and end in death related to enterovirus 71 (EV71) **T**he method applied in this activity is providing information to the community about hand, foot, and mouth disease, including its symptoms, prevention methods, and treatment. [1].

This disease is generally transmitted through direct contact with the bodily fluids of the infected person or through contaminated surfaces. Singapore flu in toddlers can cause symptoms such as fever, rashes on the hands, feet, and mouth, as well as painful sores, which can affect the child's quality of life and reduce their appetite. Singapore flu is a disease that poses a threat to the world's population, especially children under 10 years old [2]. Research results show that the system is capable of providing a diagnosis of infectious diseases in toddlers with a high level of confidence based on symptoms selected by users, thus it can be used as an early detection aid for parents and healthcare workers, Dempster-Shafer method whose final result is a diagnosis of the disease suffered by toddlers [3], [4].

This disease is highly contagious and spreads quickly, especially in densely populated environments such as daycares, schools, or households. Because the initial symptoms of Hand, Foot, and Mouth Disease are similar to other illnesses, accurate and prompt diagnosis becomes a significant challenge for healthcare professionals, especially in areas with limited health resources. Delays in diagnosis and treatment can lead to wider spread and worsen the condition of the patients, who are at greater risk, especially toddlers.

For that reason, a system is needed that can help in detecting this disease more quickly and accurately, so that it can be handled earlier and more precisely. Expert system technology can be an effective solution in this regard. Expert systems are computer applications designed to solve problems that typically require human knowledge or expertise. In this context, the expert system is used to diagnose Hand, Foot, and Mouth Disease in toddlers based on reported symptoms. One of the methods that can be used in processing symptom data for medical diagnosis is the Dempster-Shafer algorithm. This algorithm is capable of handling uncertainty and data imperfection, thus providing more accurate results even when the available information is limited or ambiguous. By utilising the Dempster-Shafer algorithm, the developed expert system is expected to provide more reliable diagnoses and support medical personnel in delivering prompt treatment.

Dempster-Shafer method. This method is used to manage uncertainty in decision-making through the combination of various information from emerging symptoms [5]. It is anticipated that the outcomes of this system will make it easier to acquire information and consultation services on ENT disorders and their symptoms, enabling the community to detect the symptoms as soon as possible and take medical action to begin the treatment process [6]. From this research, the results show that by applying the Dempster-Shafer method, it will produce percentages based on existing symptoms and be able to provide disease results and percentages to system users. From the processed data, the type of disease suffered by the child is influenza with an infection value of 0.8 and a converted probability density value of 80%. The Dempster-Shafer method is a mathematical proof theory based on the function of belief and rational arguments. [7], [8].

Therefore, this research aims to develop an expert system based on the Dempster-Shafer algorithm to detect Hand, Foot, and Mouth Disease in toddlers. Through this system, it is expected that the diagnostic process can be carried out more quickly, accurately, and efficiently, thereby helping to prevent and control the spread of this disease among children.

Literature Review

2.1 Artificial Intelligence

[9] Explain that artificial intelligence comes from the English term "Artificial Intelligence," abbreviated as AI, where intelligence is an adjective meaning smart, while artificial means man-made. The intelligence referred to here pertains to machines that are capable of thinking, weighing the actions to be taken, and making decisions like humans do. Intelligence is created and embedded into a machine (computer) so that it can be performed by humans. Some fields that use artificial intelligence include expert systems, game playing, fuzzy logic, artificial neural networks (ANN), and robotics.

2.2 Expert System

An expert system is a part of artificial intelligence that combines the fundamentals of knowledge and an inferential engine to adopt expert capabilities as a tool for solving problems in the same way that an expert would. Expert systems are a branch of Artificial Intelligence that specifically use knowledge to solve problems at an expert level. Expert systems are one of the well-known reasoning techniques used in the domain of diagnostic applications. In expert systems, human knowledge about specific expertise to solve certain tasks is represented as facts and rules in the knowledge base. An expert system is software that simulates the performance of an expert in a particular field. Expert systems are currently used in many areas where decision-making or expert predictions are required. Expert systems are artificial intelligence systems that combine a knowledge base with an inference engine, allowing them to adopt expert capabilities into computers, enabling the computers to solve problems as experts do. From several definitions, a general conclusion can be drawn that an expert system is a system that adopts the capabilities of experts, allowing the system to solve problems in a specific domain as experts typically do.

An expert system is a system that uses human knowledge. This knowledge is input into a computer and then used to solve problems that typically require human expertise or skills [10]. In the field of health, this expert system will certainly make it very easy for the community to diagnose diseases without having to meet directly with a doctor [11]. In the field of agriculture, the expert system can help farmers identify the types of diseases or pests attacking their crops [12]. Mahmoodabadi, Ahmadian, Abolhasani, Babyn, and Alirezaie (2010) conducted a study on an expert system to detect arrhythmias or patterns or rapid changes from a normal heartbeat using Fuzzy Logic. This expert system is capable of detecting 14 types of arrhythmias and heart abnormalities effectively.

A expert system is a computer system that matches the decision-making ability of an expert; the term "matches" means that the expert system is expected to work in all respects like an expert. The expert system functions very well within its domain limits. This can be proven as expert systems have been widely applied in various fields such as business, medicine, science, and engineering [13]. The internal part of an expert system consists of two main components, namely the knowledge-base, which contains knowledge, and the inference engine, which describes conclusions (Arhami, 2004). Figure 2.1 below is a diagram of the basic concept of expert system functions.

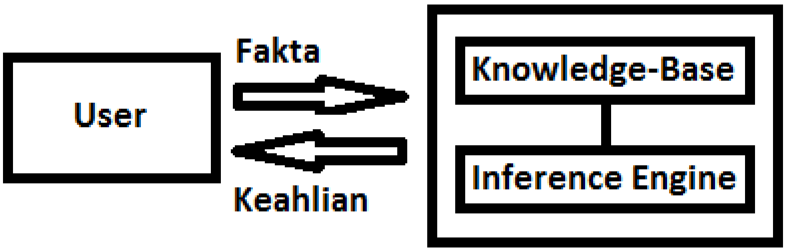

Figure 1. Expert System Diagram

The user inputs facts into the expert system, which will access the knowledge base containing knowledge to be processed by the inference engine. The facts provided by the user will produce output in the form of expertise after being processed by the inference engine. Knowledge-base or knowledge base contains knowledge for understanding, formulation, and problem-solving. The components of this expert system are composed of two basic elements, namely facts and rules. Facts are information about objects in a specific problem area, while rules are information about how to derive new facts from known facts [13]. Inference engine or inference machine is a translator of knowledge stored in the knowledge base. Inference engine explains the contents of knowledge-base and the accumulation of data on current issues from additional data and conclusions (Gonzalez, 1993).

2.3 Teori Dempster-Shafer

The Dempster-Shafer theory is a representation, combination, and propagation of uncertainty, where this theory has several characteristics that intuitively align with the way an expert thinks, but with a strong mathematical foundation.

The Dempster-Shafer theory is expressed in an interval: [Belief, Plausibility]. Where the belief value (Bel) is a measure of the strength of evidence in supporting a set of propositions. If it has a value of 0, it indicates that there is no evidence, and if it has a value of 1, it indicates certainty. Plausibility (Pls) will reduce the level of certainty of an evidence. Plausibility ranges from 0 to 1. If one is certain about X', it can be said that Bel(X') = 1, thus the value of Pls(X') = 0. The belief function can be formulated and shown in the following equation 2.1.

$$Bel\ (X) = \sum_{Y \sqsubseteq X} \boldsymbol{m}\ (\boldsymbol{Y})$$

And Plausibility is shown in the equation

$$Pls\ (X) = 1 - Bel\ (X) = 1 - \sum_{Y \sqsubseteq X} \boldsymbol{m}\ (\boldsymbol{Y})$$

Where:
Bel (X) = Belief (X)
Pls (X) = Plausibility(X)
m(X) = mass function dari (X)
m(Y) = mass function dari (Y)

In the Dempster-Shafer theory, there is a frame of discernment (FOD) or environment, which is a universe of discourse from a set of hypotheses denoted by Θ, and a mass function, often referred to as an evidence measure, which represents the degree of belief in a certain evidence (symptom) denoted by m.

In the application of the Dempster-Shafer method, there are several pieces of evidence that will be used in the uncertainty factor in the decision-making process. Therefore, Dempster's rule of combination will be used to address the existing evidence. The equation for Dempster's rule of combination to combine m1 and m2 into m3 can be seen in the formula below:

$$m_3\ (Z) = \frac{\sum \boldsymbol{xny=z}\ \boldsymbol{m1}\ (\boldsymbol{X}).\boldsymbol{m2}\ (\boldsymbol{y})}{\boldsymbol{1-K}}$$

Where K can be formulated in the equation below

$$K = \sum_{\boldsymbol{XnY=0}} \boldsymbol{m1}\ (\boldsymbol{X}).\boldsymbol{m2}\ (\boldsymbol{Y})$$

Thus, if the formula is substituted into the formula, an equation will be formed as shown in the formula.

$$m_3(Z) = \frac{\sum_{X\cap Y=Z} m_1(X).m_2(Y)}{1 - \sum_{X\cap Y=\emptyset} m_1(X).m_2(Y)}$$

2.4 Understanding of a virus

The word virus comes from the Latin word virion, which means poison, and was first used in English in 1392. The definition of "an agent that causes infectious disease" was first used in 1728, before the virus itself was discovered by Dmitry Iwanovsky in 1892 [14].

Virus are microscopic parasites that infect the cells of biological organisms. Viruses are obligate parasites, which means they can only reproduce within the living cells of a host by invading and utilising the host's cells because viruses do not have the cellular machinery to reproduce on their own. Usually, viruses contain a small amount of nucleic acids (DNA or RNA, but not a combination of both) that are enveloped in a protective material consisting of proteins, lipids, glycoproteins, or a combination of the three. The viral genome will be expressed into either proteins used to carry genetic material or proteins needed in its life cycle (Hasdianah and Dewi, 2014).

2.5 Singapore Flu

Singapore Flu, or in medical terms known as Hand, Foot and Mouth Disease (HFMD), is an infectious disease that often affects children aged 2 weeks to 5 years (even up to 10 years). Adults are generally immune to this disease, which has an incubation period of 2-5 days. HFMD is caused by Coxsackievirus A type 16 (CV A16) with various strains, namely Coxsackievirus A5, A7, A9, A10, B2, and B5 [15]

The symptoms that arise when infected with Hand, Foot, and Mouth Disease (HFMD) include a fever lasting 2-3 days, accompanied by loss of appetite, a runny nose, and general flu-like symptoms. Next, thrush will appear (on the tongue, gums, inner cheeks) and rashes will develop on the hands and feet [15].

The transmission of Hand, Foot and Mouth Disease occurs through direct contact from person to person, namely through droplets (small particles produced when someone coughs/sneezes), nasal mucus, and saliva. Indirect transmission can also occur, for example, through the shared use of towels, clothes, eating utensils, and toys. Usually, this disease appears in the summer [16].

The interval from when an individual is infected until the disease appears (incubation period) for hand, foot, and mouth disease is 2 to 5 days. After passing through the latent/incubation period, individuals with hand, foot, and mouth disease can infect others. Children affected by this disease can recover, but they can be reinfected with a different strain of the virus. However, if complications occur, it can lead to meningitis and myocarditis, which can result in death.

Methods

Primary data is obtained directly from experts or medical personnel through interviews, discussions, and knowledge validation. This primary data includes a list of Singapore flu symptoms, the relationship between symptoms and the disease, as well as the confidence value or degree of certainty regarding each symptom. Secondary data is obtained from various written sources such as books, scientific journals, health articles, medical documentation, and other references that support the research. This data is used to strengthen the theoretical foundation, understand the characteristics of the Singapore flu disease, and support the development of the expert system knowledge base.

Observation was conducted to directly observe the disease identification process in toddlers, especially related to the symptoms of Hand, Foot, and Mouth Disease (HFMD). Through observation, researchers can understand the initial examination flow and the system requirements to be built. Interviews were conducted with experts or medical personnel to obtain more in-depth information regarding the symptoms, disease characteristics, diagnosis determination methods, and the confidence level in the relationship between symptoms and HFMD. The results of these interviews serve as the main basis for forming the system's knowledge base. Additionally, a literature review was conducted by examining theories related to expert systems, HFMD, the Dempster-Shafer algorithm, and system development methods. The literature review is used to strengthen the theoretical framework and support the scientific validity of the research.

Result and Discussion

Designing the Case-Based Reasoning Method

The Case-Based Reasoning (CBR) method is one of the knowledge-based approaches to studying and solving problems based on past experiences. A new case is resolved by searching for cases stored in the case base that have similarity with the new case.

a. Case Similarity

Measurement In searching for cases that are similar to the new case, each new case will be compared with all cases in the case base using the following factors,

Table 1. Factor components in each case

Factor of the Part in Each Case
Child's Age
Symptoms
Disease
Therapy

but only two factors are used to measure similarity, namely the child's age and symptoms. Meanwhile, the factors of the disease and therapy are not included in the measurement.

The measurement of case similarity is:

$$Stotal = \frac{A1 + A2}{Ntotal}$$

Explanation:
Stotal is the total similarity or total resemblance
A1 is factor A1, which is the age factor of the autistic child
A2 is factor A2, which is the symptom factor
Ntotal is the total input

Table 2. Factor A1 or child's age

Child Age Code	Child Age
U1.	0-1 Tahun
U2.	1-2 Tahun
U3.	Diatas 2 Tahun

Table 3. Factor A2 or Symptoms of a Child Infected with a Virus

Symptoms Code	Symptoms
G1	Fever
G2	Decreased appetite
G3	Body ache
G4	Sore throat
G5	Pain when swallowing
G6	Red spots appeared in the mouth cavity that turned into canker sores.
G7	Red spots on the legs and arms
G8	Red spots or rashes on the elbows, knees, buttocks, and around the genital area

Table 4. Case Base Stored in the Database

Case	Age/**A1**	Symptoms/**A2**	**Disease**
K1	U1	G2,G6,G7,G8	S1
K2	U2	G2, G3,G5,G6,G8	S2
K3	U3	G2,G5,G6,G7,G8	S1
K4	U3	G3,G4,G7,G8	S3
K5	U1	G1, G2,G4, G5,G6,G7	S1

Example Case I

For instance, there is a new case containing data on a 2-year-old autistic child, with symptoms G2, G3, G4, G5, G7. What type of autism does the child have?
The measurement of case similarity is:

$$Stotal = \frac{A1 + A2}{Ntotal}$$

A1 = U2 (N is counted as 1 input)
A2 = G2,G3,G4,G5,G7 (N is counted as 5 input)
Ntotal = 6 input

$$\text{Stotal} = \frac{A1 + A2}{\text{Ntotal}}$$

$$\text{Stotal} = \frac{U2 + (G2,G3,G4,G5,G7)}{6}$$

Then the new case will be compared with the baseline case that has already been stored in the database, namely Table 4. Therefore, the calculation is as follows:

Explanation:

a. C1 (Case 1)
A1 = U1 Does not have any resemblance= 0
A2 = **G2**,G5,G6,G6 Does not have any resemblance= 1
Stotal = 1/6 = 0,16 =16%

b. C2 (Case 2)
A1 = U2 Does not have any resemblance = 1
A2 = **G2,G3,G5,G6,G7** 5 similarity = 5
Stotal = 6/6 = 1 = 100%

c. C3 (Kasus 3)
A1 = U3 Does not have any resemblance= 0
A2 = **G2,G3**,G5,G7,G8 2 similarity = 2
Stotal = 2/6 = 0.33 =33%

d. C4 (Kasus 4)
A1 = U3 Does not have any resemblance= 0
A2 = **G3,G5,G7**,G8 3 similarity = 3
Stotal = 3/6 = 0.5 = 50%

e. C5 (Kasus 5)
A1 = U1 Does not have any resemblance= 0
A2 = G1, **G2**,G4, G5,G7,G8 1 similarity = 1
Stotal = 1/6 = 0,16 =16%

Table 5. Total similarity scores

Basis Case	**Value A1**	**Value A2**	**Stotal / Ntotal**
C1	0	1	1/6
C2	***1***	***5***	***6/6***
C3	0	2	2/6
C4	0	3	3/6
C5	0	1	1/6

The criteria for case selection are cases that have the highest similarity to the new case that will be suggested as a solution. However, not every new case necessarily has a sufficiently high similarity value with the case base. Therefore, similarity criteria need to be established by calculating the decimal value of each Stotal or similarity value. The criteria for dividing the Stotal value are as follows:

Table 6. Similarity Criteria

Decimal Similarity Value	Percentage (%) Similarity	Similarity criteria
0.8 - 1	above 80%	*High*
0,4 – 0.79	40% - 79%	*Medium*
0 – 0.39	0% - 39%	*Low*

Based on the similarity criteria table, each case in the case base has similarity criteria with the new case as follows:

Table 7. Results of Similarity Criteria for Each Case With the New Case

Basis Case	Value A1	Value A2	Stotal	Decimal	Presentation (%)	Kriteria kemiripan
K1	0	1	1/6	0.16	16%	*Low*
K2	***1***	**5**	***6/6***	***1***	***100%***	***High***
K3	0	2	2/6	0.33	33%	*Low*
K4	0	3	3/6	0.5	50%	*Medium*
K5	0	1	1/6	0.16	16%	*Low*

Therefore, case K2 will be chosen as the recommended solution for the new case. Because it has HFMD similarity criteria as shown in the table above. In other words, the new case is likely to be disease K2 = Hand, Foot, and Mouth Disease.

Conclusion

Based on the background description, abstract, and research methodology, it can be concluded that Hand, Foot, and Mouth Disease is one of the infectious diseases that often affects toddlers and requires prompt and accurate handling. The early detection process is very important because the symptoms of this disease often resemble the symptoms of other diseases, which can lead to uncertainty in initial decision-making. This condition indicates the need for an auxiliary medium that can provide initial information systematically and logically. This research focuses on the development of an expert system designed to help detect Hand, Foot, and Mouth Disease in toddlers based on the symptoms that appear. By utilising the Dempster Shafer algorithm, the system can process symptom data and the level of confidence from experts to generate a trust value regarding the likelihood of the detected disease. This method is considered appropriate because it can handle uncertainty and information limitations in the initial diagnosis process.

Through this research, it is hoped that the developed expert system can become an effective tool for the community, especially parents, in recognising the possible symptoms of Hand, Foot, and Mouth Disease (HFMD) in toddlers at an earlier stage. Additionally, this system can also support healthcare professionals in providing initial considerations before further examinations are conducted. Thus, this research not only contributes to the field of information technology but also has practical benefits in the field of child health.

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