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EXPERT SYSTEM FOR DIAGNOSING BEHAVIORAL DISORDERS USING THE DEMPSTER-SHAFER THEORY ALGORITHM

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ABSTRACT

Behavioral disorders, especially in children, can have a significant impact on their development in various domains, such as social, emotional, and academic. The diagnostic process for this disorder can be complicated due to overlapping symptoms and the possibility of complex causal factors. Early identification and appropriate treatment of behavioral disorders is essential to prevent more serious impacts on an individual's psychological well-being. Lack of knowledge and difficulty in accessing psychiatrists to find out about behavioral disorders in children are factors that result in this problem requiring a solution. The aim of this research is to create an expert system that utilizes the Dempster-Shafer Theory algorithm to detect behavioral disorders, thus simplifying the diagnosis process and ensuring accurate results. The Dempster-Shafer theory, as an inference engine, can overcome uncertainty by combining several sources of evidence or data that may overlap or be incomplete, resulting in a stronger conclusion. The main feature of this expert system is its ability to carry out diagnoses based on symptoms and display diagnosis results, disease descriptions, and treatment options. Test accuracy produces a value of 90%, which shows that the Dempster-Shafer Theory approach can diagnose behavioral disorders effectively.

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INTRODUCTION

Behavioral disorders are mental health problems that can significantly affect a person's quality of life. Behavioral disorders in children can have a significant impact on their development in various domains, such as social, emotional, and academic [1]. Children with behavioral disorders may have difficulty building healthy interpersonal relationships, interacting with their surroundings, and managing their emotions effectively [2]. Behavioral disorders can also hinder a child's ability to learn and participate in academic activities, potentially affecting their school performance [3]. The diagnostic process for this disorder can be complicated due to overlapping symptoms and the possibility of complex causal factors. Lack of knowledge and difficulty in accessing psychiatrists to find out about behavioral disorders in children are factors that result in this problem requiring a solution. Early identification and appropriate treatment of behavioral disorders is essential to prevent more serious impacts on an individual's psychological well-being. In this modern era, information technology and artificial intelligence have become an integral part of various areas of life, including mental health [4]. Therefore, the development of an expert system is a promising solution to assist users in providing appropriate interventions.

There has not been much research regarding the development of an expert system for detecting behavioral disorders, but research related to mental disorders in children has been carried out by several researchers. The first research concerns the development of an expert system for diagnosing anxiety disorders using the Dempster-Shafer Theory approach. This research resulted in an accuracy of 85% [5]. Further research concerns the application of the Dempster-Shafer Theory algorithm to the psychological diagnosis of impulse control disorders [6]. The model developed produces an accuracy rate of 85%. Other research on expert systems for diagnosing brain development disorders in children uses the Dempster-Shafer Theory approach [7]. The results of system testing by experts obtained an average percentage of 90%. Based on previous research, it shows that the Dempster-Shafer Theory algorithm has good accuracy when applied as an inference engine in expert systems. This is because the Dempster-Shafer Theory has the ability to overcome situations where information is not completely reliable or data uncertainty is very high [8]. The Dempster-Shafer Theory allows the integration of evidence from various sources with varying levels of confidence.

So, the aim of this research is to create an expert system that utilizes the Dempster-Shafer Theory algorithm to detect behavioral disorders in children in order to simplify the diagnosis process and ensure an accurate diagnosis. The Dempster-Shafer Theory approach is a mathematical framework that is able to overcome uncertainty by combining evidence from various sources to produce more accurate estimates [9]. This approach can accommodate incomplete or ambiguous information, which often appears in the real world [6]. In addition, the Dempster-Shafer Theory algorithm allows combining various sources of information that are related to each other, including information that is conflicting or inconsistent. The contribution to this research is to focus on mental illnesses specifically behavioral disorders in children and use the Dempster-Shafer Theory with sources of knowledge obtained from psychiatrists. Apart from that, an expert system is designed and implemented on the website platform to provide easy accessibility and use.

RESEARCH METHODS

To answer research questions, a systematic approach is needed to plan, implement and evaluate. This research approach involves certain stages to achieve the research objectives[10]. So, so that the research can proceed in accordance with the research objectives, the research stages are arranged as shown in Figure 1.

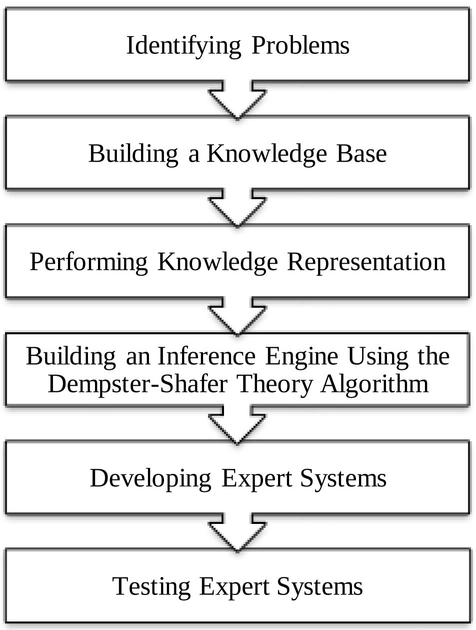

Figure 1. Phases of Research Carried Out

For more clarity, the description of the research phases visualized in Figure 1 is as follows.

A. Identifying Problems

At this stage, an analysis of a situation or context will be carried out to identify problems or challenges that need to be solved. To find problems that will be resolved, interviews and observations are carried out regarding the identification of obstacles or difficulties in diagnosing behavioral disorders in children. Based on the results of interviews and observations, the main problem was found to be a lack of knowledge and difficulty in accessing psychiatrists to find out about behavioral disorders in children. Early identification and appropriate treatment of behavioral disorders in children is crucial to prevent more serious impacts and improve individual well-being. For this reason, expert systems can be an alternative in solving this problem.

B. Building a Knowledge Base

Knowledge base refers to a collection of information, facts, concepts, and rules that are stored and organized in a system or entity [11]. A knowledge base includes a knowledge structure used to store information, rules and specific domain knowledge that is relevant to the function of the expert system. For this reason, at this stage, knowledge will be collected regarding symptoms, types of disease and how to treat behavioral disorders in children obtained from knowledge sources such as related books and psychiatrists.

C. Performing Knowledge Representation

Knowledge representation in expert systems refers to the way domain-specific information and knowledge is represented and stored in the system [12]. Knowledge representation aims to present information in a way that can be understood and processed by machines. In this study, the knowledge that has been obtained from an expert will be represented in the form of a decision table so that the rules of the symptoms that exist for the disease can be known.

D. Building an Inference Engine Using the Dempster-Shafer Theory Algorithm

The inference engine works by applying logical rules or knowledge contained in the system's knowledge base [13]. In this research, the development of an inference engine is related to the process of applying rules acquired from an expert using the Dempster-Shafer Theory algorithm. Dempster-Shafer Theory is a framework in decision theory and evidence theory developed by Glenn Shafer in 1976 and further developed together with Arthur P. Dempster [14]. This theory provides a powerful approach to dealing with uncertainty in decision making, especially when there is a lot of incomplete or overlapping evidence [15]. The Dempster-Shafer Theory algorithm focuses on representing uncertainty using the concept of mass set, which measures the extent to which a statement or hypothesis has support from existing evidence [16]. These algorithms provide a flexible framework for processing information from various sources, even if the information is not completely clean or conflicting [17].

A number of belief functions in the Dempster-Shafer Theory represent the level of belief in various propositions or events [18]. A belief with a score of 0 indicates a lack of evidence, whereas a score of 1 indicates the presence of evidence. The belief function may be expressed using equation (1).

$$Bel(X) = \sum_{\subset X} m\,(Y) \quad (1)$$

where $Bel(X)$ is the belief function on the variable (X) and $m(Y)$ is the mass function on the attribute (Y).

In order to obtain the plausibility value, it is calculated using equation (2).

$$Pls(X) = 1 - Bel(X') = 1 - \sum_{Y \subset X}^{n} m\,(X') \quad (2)$$

where $Pls(X)$ is a trust function which has a value between 0 and 1.

However, in fact, in its application to expert systems, elements emerge that result in uncertainty in the user's answers. Everything that is possible in this algorithm is called the power set which is denoted by $P(\theta)$. To get the value, it is computed using equation (3).

$$m = P(\theta) \quad (3)$$

where m refers to the mass function score, then $P(\theta)$ represents the power series score.

The use of the Dempster-Shafer Theory develops with the use of evidence regarding uncertain variables in finding a solution. Dempster's combination rule was applied to address the issue of handling large amounts of evidence. This approach integrates evidence, namely m_1 and m_2, using equation (4).

$$m_1 \oplus m_2(Z) = \sum_{X \cap Y = Z} m_1(X) m_2(Y) \quad (4)$$

where $m_1 \oplus m_2(Z)$ shows the combination of mass function values for evidence produced by m_1 and m_2, $m_1(X)$ shows the mass function produced by evidence $m_2(Y)$ shows the mass function produced on evidence (Y), and $\oplus$ as operators that perform sum.

Subsequently, equation (5) is used to derive Dempster's rule of combination.

$$m_1 \oplus m_2(Z) = \frac{\sum_{X \cap Y = Z} m_1(X) m_2(Y)}{1 - k} \quad (5)$$

In equation (5), k shows the number of conflicting pieces of evidence that exist, so to obtain the total value of k, equation (6) is applied.

$$k = \sum_{X \cap Y = \theta} m_1(X) m_2(Y) \quad (6)$$

where $m_1 \oplus m_2$ refers to the combination of m_1 and m_2 which then results in the combination being m_3.

In order to make the calculation process easier, the value of this combination can be obtained through equation (7).

$$m_3(Z) = \frac{\sum_{X \cap Y = Z} m_1(X) m_2(Y)}{1 - \sum_{X \cap Y = \theta} m_1(X) m_2(Y)} \quad (7)$$

C. Developing Expert Systems

Building a system or the process of implementing a system refers to the action of converting what is obtained when carrying out analysis and modeling into a language that the computer understands as software [18]. This expert system was created using a website framework, using the Atom code editor and MySQL as the database.

E. Testing Expert Systems

The testing process is conducted to ascertain the performance and evaluate the degree to which the established model or system can provide precise and consistent outcomes [19]. The test is carried out through accuracy testing, where the model or system is measured on its ability to predict results that are correct or in accordance with existing data. The accuracy metric is derived by comparing the system's findings with the expert diagnostic outcomes. The accuracy measure is derived by comparing the outcomes produced by the system with the expert diagnostic outcomes. To get the accuracy value, equation (1) is used.

$$Accuracy = \frac{NC}{NT} \times 100\% \quad (8)$$

where NC refers to the number of correctly diagnosed data and NT refers to the number of test data.

RESULTS AND DISCUSSION

To create an expert system that can diagnose behavioral disorders in children using the Dempster-Shafer Theory algorithm, the first step is to collect the necessary information. Furthermore, the accumulated knowledge serves as the knowledge base. This knowledge is obtained from a psychiatrist, including symptoms, diseases, and appropriate treatment methods. This case study examines four forms of behavioral disorders seen in children. Table 1 displays a compilation of the diseases used.

Table 1. Types of Cerebral Palsy

Disease Code	The Type of Disease
D1	Attention Deficit Hyperactivity Disorder (ADHD)
D2	Oppositional Defiant Disorder (ODD)
D3	Autism Spectrum Disorder (ASD)
D4	Conduct Disorder (CD)

Table 1 contains the types of behavioral disorders in children and then data on the symptoms are collected from these types of diseases. So, a list of 20 symptoms is obtained and a density value is given. The density value for each symptom is given by experts by giving a value between 0 and 1. The list of symptoms, types of disease, and density values is shown in Table 2.

Table 2. List of Symptoms, Diseases and Density Values

Code	Symptoms	The Type of Disease	Density Value
S1	Restless and difficult to stay still or often move around.	D1	0.8
S2	Careless and talkative.	D1	0.6
S3	It's easy to forget instructions.	D1	0.7
S4	Difficulty concentrating or being easily distracted.	D1, D3	0.7
S5	Likes to interfere with other people's activities.	D1, D4	0.8
S6	Taking action without considering the risks.	D1, D2, D4	0.6
S7	Often doing repetitive movements such as shaking your legs or wringing your hands.	D1, D3	0.7
S8	It's easy to get angry.	D1, D2, D3, D4	0.7
S9	If you cry very loudly, have a tantrum, or even roll on the floor.	D2	0.9
S10	Defiant attitudes that often resist or defy adult orders.	D2, D4	0.5
S11	Deliberately annoying or bullying other people.	D2, D4	0.6
S12	Not confident.	D2	0.7
S13	It's very easy to get frustrated.	D2	0.4
S14	Difficulty in communicating, including speaking or social interaction.	D3	0.8
S15	Routinely carry out certain activities and get angry if the routine is disturbed.	D3	0.7
S16	Only liking or consuming certain foods.	D3	0.5
S17	Likes to lie and cheat.	D4	0.6
S18	Aggressive behavior towards other people or animals.	D4	0.8
S19	Lack of empathy for others.	D4	0.7
S20	Do not hesitate to commit acts that violate the law, such as vandalism, fighting, or injuring other people.	D4	0.6

The inference engine used in this research applies the Dempster-Shafer Theory approach. This framework focuses on representing uncertainty using the concept of mass set, which measures the extent to which a statement or hypothesis has support from existing evidence. The researchers use the following symptoms as a case study to solve the problem of diagnosing behavioral disorders in children:

Symptom S3 : It's easy to forget instructions.
Symptom S5 : Likes to interfere with other people's activities.
Symptom S6 : Taking action without considering the risks.

To In the case study, S3 symptoms had a density score of 0.7. These symptoms are indicative of Attention Deficit Hyperactivity Disorder (ADHD) (D1). So, the mass function values obtained are as follows:

$$m_1\ \{\text{D1}\} = 0{,}7$$
$$m_1\ \{\theta\} = 1 - 0{,}7 = 0{,}3$$

The next symptom is S5 which has a density score of 0.8. These symptoms are indicative of

Attention Deficit Hyperactivity Disorder (ADHD) (D1) and Conduct Disorder (CD) (D4). So the mass function values obtained are as follows:

$$m_2\ \{\mathrm{D1.D2}\} = 0{,}8$$
$$m_2\ \{\theta\} = 1 - 0{,}8 = 0{,}2$$

After the density scores S3 and S5 are obtained, continue by calculating the combined value of the two densities called m_1 and m_2 using the combination rule table according to equation (7). Combining these two densities is used to obtain a confidence measure for a new event. Guidelines for combining S3 and S5 symptoms to obtain this combination are outlined in Table 3.

Table 3. Combination of Rules for m_3

		{D1, D4}	(0.8)	θ	(0.2)
{D1}	(0.7)	{D1}	(0.56)	{D1}	(0.14)
θ	(0.3)	{D1, D2}	(0.24)	θ	(0.06)

In Table 3 are the results of combining G1 and G7 to obtain a new combination value. Combining the densities m_1 and m_2 becomes m_3 which is found using equation (7). So, to get the combination m_3 is as follows:

$$m_3\ \{\mathrm{D1.D4}\} = \frac{0{,}24}{1-0} = 0.24$$
$$m_3\ \{\mathrm{D1}\} = \frac{0{,}56 + 0{,}14}{1-0} = 0{,}7$$
$$m_3\ \{\theta\} = \frac{0{,}06}{1-0} = 0{,}06$$

Then the next symptom is S6 which has a density value of 0.6. The symptoms described correspond to Attention Deficit Hyperactivity Disorder (ADHD) (D1), Oppositional Defiant Disorder (ODD) (D2), and Conduct Disorder (CD) (D4). So the mass function values obtained are as follows:

$$m_4\ \{\mathrm{D1.D2.D4}\} = 0{,}6$$
$$m_4\ \{\theta\} = 1 - 0.6 = 0{,}4$$

After obtaining the symptom density values S3, S5, and S6, continue to calculate the combination values by referring to the combination rules table presented in Table 4.

Table 4. Combination of Rules for m_5

		{D1, D2, D4}	(0.6)	θ	(0.4)
{D1, D4}	(0.24)	{D1, D4}	(0.144)	{D1, D4)}	(0.096)
{D1}	(0.7)	{D1}	(0.42)	{D1}	(0.28)
θ	(0.3)	{D1, D2, D4}	(0.18)	θ	(0.12)

In Table 4 are the results of combining S3, S5 and S6 to obtain a new combination value. Combining these density combinations will form m_5. According to equation (7), the calculating procedure may be described as follows:

$$m_5\ \{\mathrm{D1.D4}\} = \frac{0{,}144 + 0{,}096}{1-0} = 0{,}24$$
$$m_5\ \{\mathrm{D1.D2.D4}\} = \frac{0{,}18}{1-0} = 0{,}18$$
$$m_5\ \{\mathrm{D1}\} = \frac{0{,}42 + 0{,}28}{1-0} = 0{,}7$$
$$m_3\ \{\theta\} = \frac{0{,}12}{1-0} = 0{,}12$$

By calculating the aggregate density m_5, all the symptoms in this case study have been consolidated. Therefore, it is evident that the maximum value is D1, which corresponds to a value of 0.7 or 70%. The diagnosis derived from this case study is Attention Deficit Hyperactivity Disorder (ADHD).

This expert system was created using a website and a coding editor called Atom, as well as a MySQL database. This expert system diagnoses behavioral disorders in children. It includes features such as symptom and disease data management, use of the principles of the Dempster-Shafer Theory, generation of diagnoses, visualization of diagnostic findings, and guidance on how to treat them. The main page of the expert system for diagnosing behavioral disorders in children is presented in Figure 2.

Figure 2. Main Page

Within this system, there are two distinct categories of users: administrators and patients. Administrators have the ability to enter data, including symptom data, illnesses, and criteria based on Dempster-Shafer Theory. The user interface for the disease data management page is presented in Figure 3.

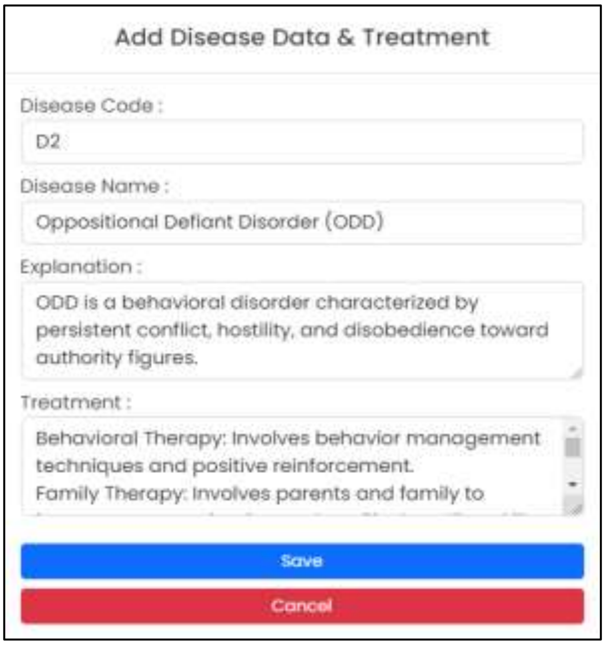

Figure 3. Page for Entering Disease Data

After the data has been input by the administrator, the patient or user can make a diagnosis. In the main menu, users are presented with features that can be accessed, including: starting a consultation and a list of behavioral disorders in children. The diagnostic page for users is presented in Figure 4.

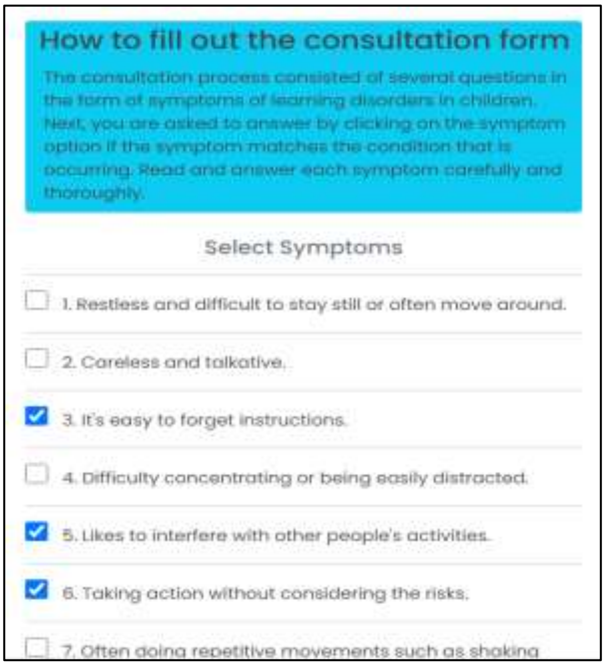

Figure 4. Diagnostics Page

Figure 4 shows the diagnosis page, where users can fill in the symptoms, they are experiencing by carrying out a checklist. After the user fills in the symptoms they are experiencing, the user can continue by pressing the diagnosis button. The system will display diagnostic results using the Dempster-Shafer Theory inference engine. The user diagnosis results are presented in Figure 5.

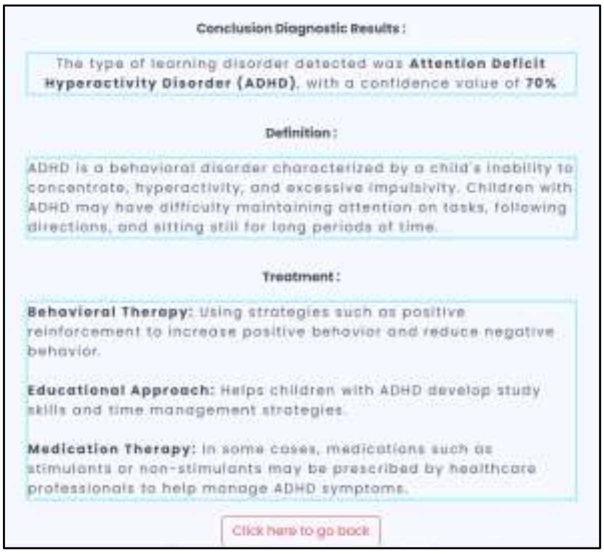

Figure 5. Diagnostic Results Page

Figure 5 illustrates the diagnostic outcomes, presenting the illness kind and the calculated confidence level using the Dempster-Shafer Theory technique, along with the corresponding handling procedures. The results of calculations using the same case study as manual calculations do not show different results, this shows that the Dempster-Shafer Theory calculations output from the system can be said to be "valid".

After the expert system has been implemented, the next process is to test the system. This is to determine the performance of the expert system being developed. To measure its performance, testing is carried out on the accuracy of the diagnostic results. The test sample applied was 30 test cases using random symptoms. To get the accuracy value, the results of the diagnosis by the expert system and the results of the psychiatrist's diagnosis will be compared. Of the 30 test cases, 27 cases had corrected diagnoses and 3 cases had incorrect diagnoses. These results are calculated to obtain accuracy values using equation (8). So, the calculation is as follows:

$$Accuracy = \frac{27}{3} \times 100\% = 90\%$$

The resulting accuracy value is 90% obtained from the testing process, and the error rate is 10%.These results are then made in graphic form which is visualized in Figure 6.

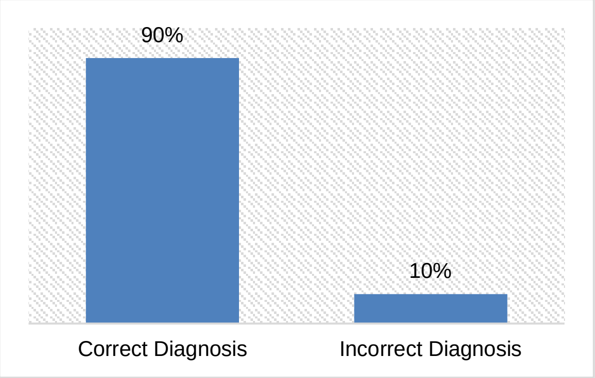

Figure 6. Accuracy Test Percentage Graph

Figure 6 is a graph illustrating the results of accuracy tests, with a 90% success rate in correctly diagnosing the condition.These results are then converted into criteria groups with reference to the following assessment: "Not Good" with a score of less than 40%; “Not Good” with a value of 40% to 55%; “Quite Good” with a score of 56% to 75%; "Good" with a score of 76% to 100% [20]. Therefore, after evaluating these criteria, the expert system that was constructed is categorized inside the "Good" category. This accuracy is influenced by the performance of the Dempster-Shafer Theory algorithm which is able to overcome problems where there are several sources of evidence or data that may overlap or be incomplete, and a way is needed to combine them into one stronger conclusion. However, this 10% incorrect diagnosis occurs due to several factors including: This algorithm depends on good initial knowledge about the problem domain, such as determining density values and the relationship between symptoms and disease. Errors in determining this initial knowledge can affect the diagnosis results. Apart from that, in case studies of diagnosing behavioral disorders in children, there are several diseases that have similar symptoms.

CONCLUSION

This research has developed an expert system for diagnosing behavioral disorders by applying an inference engine, namely the Dempster-Shafer Theory method. By considering the level of confidence in a particular event based on existing evidence, the method overcomes uncertainty. A web-based expert system capable of conducting diagnostics using symptoms and presenting diagnosis outcomes, illness explanations, and treatment methods. The test results indicate an accuracy level of 90%, which falls within the "Good" threshold. This means that the Dempster-Shafer Theory approach can be well implemented to diagnose behavioral disorders in children. For further research, there are several things that can be improved. There needs to be a method to determine the level of confidence to obtain a valid density value. The Dempster-Shafer Theory method may be integrated with Fuzzy Logic to facilitate the determination of density values provided by experts.

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