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Comparison of Certainty Factor, Dempster Shafer, and Bayes' Theorem in Expert Systems for Diagnosing Female Reproductive System Diseases

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Abstract−Expert systems are one application of artificial intelligence used to mimic the ability of an expert in diagnosing a disease. This study aims to compare the performance of three inference methods Certainty Factor, Dempster-Shafer, and Bayes' Theorem in the diagnosis of female reproductive system diseases. Symptom data and expert knowledge values were obtained from medical experts to support the system's validity. Each method was implemented on the same symptom data, and the results were analyzed to assess the consistency of the diagnoses produced. The results show that the Certainty Factor method produced a diagnosis of Cervical Cancer with the highest confidence value of 0.9999, followed by the Dempster-Shafer method with the same diagnosis and a confidence value of 0.852. However, the Bayes Theorem method produced a different diagnosis, namely Ovarian Cyst, with a confidence value of 0.911. These differing results indicate that the characteristics and approaches of each method significantly influence the final diagnosis outcome. This study contributes insights to expert system developers regarding the strengths and weaknesses of each inference method. The selection of the appropriate method must be tailored to the system's requirements, data complexity, and the level of uncertainty in the medical information used.

Keywords: Expert System; Female Reproductive System; Certainty Factor, Dempster-Shafer; Bayes Theorem

1. INTRODUCTION

Women's reproductive health is an important part of the public health system that directly affects the quality of life of women and the sustainability of future generations[1]. The female reproductive system has a complex biological structure and is highly susceptible to various types of diseases, ranging from mild to chronic[2]. Diseases such as ovarian cysts, uterine fibroids, endometriosis, reproductive tract infections, and cervical cancer are some of the common disorders experienced by women of reproductive age. Early detection and accurate diagnosis of these diseases are crucial, as delayed or incorrect treatment can lead to serious complications, even life-threatening ones.

However, in practice, not all women have adequate access to health services or competent medical personnel specializing in reproductive health. Limited facilities, a shortage of healthcare workers, and the distance between medical services and people's homes are particular challenges, especially in remote areas. In this context, information technology, particularly expert systems, offers an alternative solution that can provide support in the initial diagnosis process in a fast, accurate, and efficient manner.

Expert systems are a branch of artificial intelligence (AI) designed to mimic the way human experts think and act in solving specific problems. These systems work based on a knowledge base and an inference engine that process information from users (in this case, medical symptoms) to generate conclusions or diagnoses [3][4]. One of the main challenges in expert systems, particularly in the medical field, is the uncertainty of information. The symptoms experienced by patients are often subjective, overlap between diseases, and have a low degree of certainty.

To address this uncertainty, several inference methods have been developed and used in expert systems. These include the Certainty Factor (CF) method, Dempster Shafer Theory (DST), and Bayes' Theorem. All three have different approaches to handling uncertainty and formulating probabilities for a hypothesis or diagnosis.

The Certainty Factor is a rule-based method used to represent an expert's level of confidence in the relationship between symptoms and a particular disease. CF uses confidence (MB) and disbelief (MD) values to determine the degree of certainty of a conclusion. The advantage of CF lies in its ease of implementation and computational efficiency, but its weakness is that it is highly dependent on the subjectivity of the expert [5][6][7].

The Dempster-Shafer Theory, also known as the belief theory, is a mathematical method that allows the combination of multiple pieces of evidence from various sources to form a belief in a particular hypothesis. DST does not require initial probabilities and allows for uncertainty and ignorance in the inference process. DST is particularly useful in situations where the information obtained is incomplete or ambiguous [8][9].

Meanwhile, Bayes' theorem is a statistical approach that calculates the probability of a hypothesis based on the initial probability (prior) and available evidence (likelihood). Bayes' Theorem is objective and widely used in medical applications due to its ability to handle probabilistic information in a formal and logical manner. However, the accuracy of this method is highly influenced by the availability and accuracy of historical data [10][11].

Previous studies have proven the effectiveness of the Certainty Factor, Dempster Shafer, and Bayes Theorem methods in building expert systems in various fields, particularly in the mental health and medical domains. A study conducted by Fernando et al. (2024) developed an expert system for diagnosing personality disorders using the Forward Chaining approach and the Certainty Factor method. The system was tested using medical records from 10

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patients and achieved an accuracy of 98.1% for diagnosing antisocial personality disorder, as well as accuracy above 90% for other test data. Interestingly, the system was also able to identify patients with more than one type of personality disorder with varying degrees of certainty. These results indicate that the Certainty Factor is quite effective in processing complex and overlapping symptom information [12]. Meanwhile, Andrian Sah (2025) developed an expert system for diagnosing types of stress using the Dempster Shafer Theory approach. This system is capable of managing symptom data, stress types, and providing diagnostic results accompanied by recommended treatment solutions. Based on the test results, the system showed an accuracy rate of 93.33%, which is categorized as “Good” in system performance evaluation standards. This study confirms that Dempster-Shafer is effective in handling uncertainty and providing decision-making support based on evidence-based confidence [13]. Then, research by Krisantus Jumarto Tey Seran and Hevi Herlina Ullu (2025) applied the Bayes Theorem algorithm to build an expert system for diagnosing the level of depression in final year students. This study utilized 28 symptom data points and three depression severity levels (Mild, Moderate, Severe). The developed system achieved an accuracy rate of 84%, indicating that Bayes' Theorem is sufficiently effective in classifying symptoms based on probabilities calculated from previous data [14]. Kusmanto et al. (2025) conducted a comparative study between Dempster Shafer and Bayes' Theorem in expert systems for diagnosing respiratory diseases. The analysis results showed that Bayes' Theorem provided the highest confidence for tuberculosis at 74.92%, while Dempster Shafer produced the highest confidence for bronchitis at 80%. This study concludes that the effectiveness of a method depends heavily on the characteristics of the data and the type of disease being analyzed, so the choice of method must be tailored to the needs of the system [15]. Furthermore, Novanka Veldasari et al. (2022) conducted a study that directly compared the three methods, namely Certainty Factor, Dempster Shafer, and Bayes' Theorem in the early detection of mental health disorders. Each method measures the level of certainty based on existing symptoms. The results of the study showed that the Certainty Factor yielded the highest probability level at 99.4%, followed by Dempster-Shafer at 94%, and Bayes' Theorem at 81.65%. Additionally, usability testing of the web-based expert system they developed yielded a result of 80.68%, indicating that users were sufficiently satisfied with the system's interface and functionality. This study indicates that the Certainty Factor is superior in the context of mental disorder diagnosis, but all three methods still provide relevant results [16].

From these studies, it can be concluded that each method has its own advantages and disadvantages. Certainty Factor excels in terms of implementation and inference speed, Dempster Shafer is more flexible in handling uncertainty and incomplete data, while Bayes' Theorem excels in a systematic probabilistic approach. However, no specific research has been conducted to compare these three methods in the context of diagnosing women's reproductive system diseases. Therefore, this study aims to address this gap by applying and comparing the three methods within an expert system focused on the domain of women's reproductive system diseases.

Therefore, this study aims to develop and compare expert systems for diagnosing female reproductive system diseases using three uncertainty reasoning methods, namely Certainty Factor, Dempster Shafer, and Bayes' Theorem. This system will be evaluated based on several aspects, such as the accuracy of diagnostic results, sensitivity to incomplete data, and the efficiency of the inference process. Through this research, it is hoped that it will provide a tangible contribution to the development of more reliable expert systems in the field of women's reproductive health, expand access to self-diagnosis, and serve as an important reference for expert system developers in selecting the appropriate inference method according to domain requirements.

2. RESEARCH METHODOLOGY

2.1 Research Stages

This research was conducted through several systematic stages aimed at designing and comparing expert systems for diagnosing female reproductive system diseases using three methods of uncertainty reasoning, namely Certainty Factor, Dempster Shafer, and Bayes' Theorem. Each stage was carried out gradually and in a structured manner to ensure that the developed system could be tested comprehensively and objectively. The stages of the research carried out were as follows:

a. Identification of problems
   This initial stage aims to formulate the problems that form the basis of the research, namely the need for an expert system that can assist in the diagnosis of female reproductive system diseases with a high degree of accuracy and is capable of handling the uncertainty of nonspecific symptoms.
b. Literature Study
   At this stage, various relevant scientific references on expert systems, uncertainty theory, and the Certainty Factor, Dempster Shafer, and Bayes Theorem methods were searched and collected. This literature study became the basis for building the inference model and system structure.
c. Data Collection
   The data used in the expert system consists of a list of symptoms and types of diseases of the female reproductive system. This data is obtained from reliable medical sources such as journals, health articles, and consultations with medical personnel or experts in the field of obstetrics and gynecology.
d. Application of Certainty Factor Method, Dempster Shafer, and Bayes Theorem

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After the data was collected, the three methods were applied to build three versions of the diagnostic expert system. Each method was used to form an inference mechanism based on the same symptom data. The implementation process was carried out in parallel so that comparisons between methods could be made objectively.

e. Analysis of Results
The results of each method were tested and evaluated based on several parameters, such as diagnostic accuracy, inference efficiency, and the ability to handle incomplete or ambiguous symptom data. This analysis aimed to identify the strengths and weaknesses of each inference approach in the same context.

f. Conclusion and Suggestions
This final stage summarizes the results of the analysis and provides recommendations on which method is most suitable for use in an expert system for diagnosing female reproductive system diseases. In addition, suggestions are also provided for further development of the system, both in terms of technology and disease coverage.

Figure 1 shows the systematic steps taken in this study to build and evaluate an expert system for diagnosing female reproductive system diseases using three different reasoning weighting methods, namely Certainty Factor, Dempster Shafer, and Bayes' Theorem.

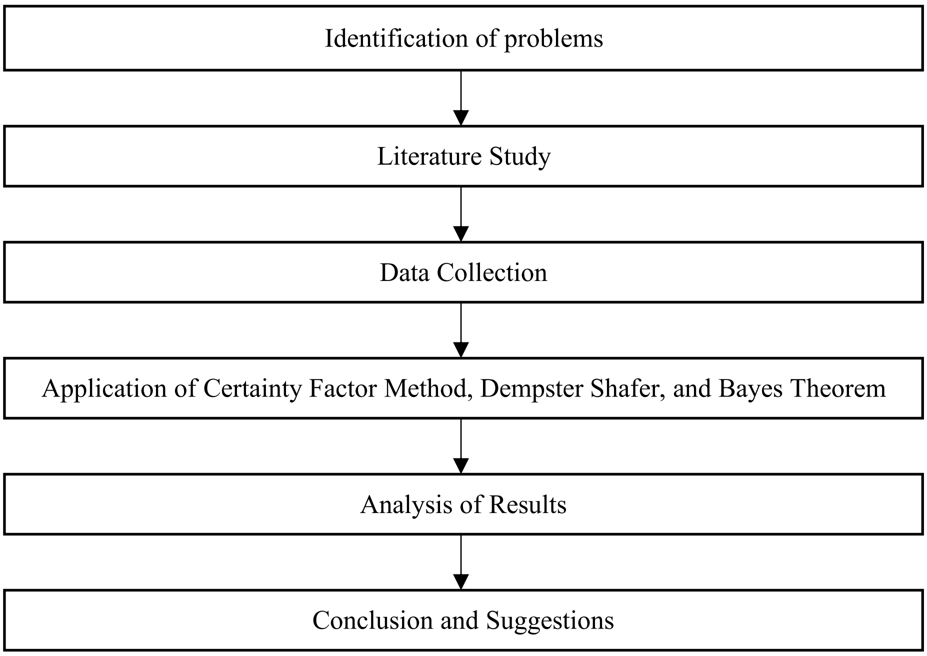

Figure 1. Research Stages

Figure 1 shows the six main steps of the research process: problem identification, literature review, data collection, application of the Certainty Factor, Dempster Shafer, and Bayes' Theorem methods, analysis of results, and drawing conclusions and recommendations.

2.2 Expert system

An expert system is a computer program designed to mimic the way an expert analyzes and solves problems in a specific domain. This system consists of three main components, namely a knowledge base, an inference engine, and a user interface [17][18]. Expert systems are very useful in the medical field, as they can assist healthcare professionals and general users in making initial diagnoses of diseases based on the symptoms entered [19][20][21]. In this study, an expert system was developed to diagnose diseases of the female reproductive system using three different inference methods, namely Certainty Factor, Dempster Shafer, and Bayes' Theorem, to compare their effectiveness.

2.3 Certainty Factor Method

The Certainty Factor (CF) is a method used to represent an expert's level of confidence or certainty regarding the relationship between symptoms and disease. CF is the result of combining the Measure of Belief (MB) and Measure of Disbelief (MD) values assigned to a fact or symptom. CF values range from -1 (no belief at all) to +1 (strong belief) [22][23]. The formula for calculating the Certainty Factor for a single symptom is [24]:

$$\mathrm{CF}(x,y) = \mathrm{CF}(x) * \mathrm{CF}(y) \quad (1)$$

If there is more than one symptom, the total CF value can be calculated using the combination formula:

$$\mathrm{CF}_{\mathrm{combine}} = \mathrm{CF}_1 + \mathrm{CF}_2 * (1 - \mathrm{CF}_1) \quad (2)$$

2.4 Dempster Shafer Method

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The Dempster Shafer Theory (DST) is a mathematical theory in decision making under uncertainty. DST develops classical probability theory by introducing the concepts of belief and plausibility [25][26][27]. The main advantage of this method is its ability to handle ignorance and incomplete evidence [28][29]. The main steps in applying DST [30]:

a. Determine the frame of discernment (the set of all possible diseases).
b. Calculate the belief mass function (basic probability assignment, BPA) based on symptoms.
c. Combining BPA values using Dempster's combination rule.
d. Generating confidence values for each disease.

The DST method is highly effective for medical cases with incomplete data or overlapping symptoms.

2.5 Bayes' Theorem Method

Bayes' theorem is a probabilistic approach to decision making that calculates the posterior probability of a hypothesis based on new evidence and initial probabilities [31][32][33]. The basic formula of Bayes' theorem is:

$$P(H|E) = \frac{[P(E|H)*P(H)]}{P(E)} \quad (3)$$

In Bayesian probability, each component has a specific role in updating beliefs based on evidence. The term P(H|E) represents the posterior probability, or the probability of a hypothesis H being true after new evidence E is considered. Meanwhile, P(E|H) refers to the likelihood, which indicates the probability of observing the evidence E given that the hypothesis H is true. The prior probability, denoted as P(H), reflects the initial belief or assumption about the hypothesis before taking any evidence into account. Lastly, P(E) stands for the probability of the evidence itself, which acts as a normalizing factor to ensure the posterior probability is valid. Together, these elements form the foundation of Bayesian inference, allowing systematic reasoning under uncertainty.

In expert systems, this method is used to calculate the likelihood of a disease based on the symptoms experienced by the patient. Bayes' Theorem provides a systematic approach to handling uncertainty based on statistical data.

2.6 Reproductive System in Women

The female reproductive system consists of several important organs such as the ovaries, fallopian tubes, uterus (womb), cervix, and vagina. This system is responsible for reproductive functions such as ovulation, menstruation, and pregnancy. However, this system is also susceptible to various disorders and diseases [34][35]. Some common diseases of the female reproductive system include:

a. Ovarian cysts: Fluid-filled sacs that grow on the ovaries.
b. Uterine fibroids: Benign tumors on the wall of the uterus.
c. Endometriosis: Endometrial tissue growing outside the uterus.
d. Reproductive tract infections: Caused by bacteria or viruses.
e. Cervical cancer: Abnormal cell growth in the cervix.

The symptoms that appear are usually nonspecific, such as lower abdominal pain, menstrual disorders, and abnormal vaginal discharge, making diagnosis often difficult to perform quickly without the assistance of medical professionals. Therefore, an artificial intelligence-based expert system can make a significant contribution in providing rapid and accurate initial diagnoses.

3. RESULTS AND DISCUSSION

3.1 Problem Analysis

Diseases of the female reproductive system are one of the most important health issues that require early and accurate diagnosis. Conditions such as cervical cancer, ovarian cysts, endometriosis, reproductive tract infections, and hormonal disorders often share overlapping symptoms, making manual diagnosis by medical professionals require high precision and extensive experience. In this context, expert systems can serve as a solution to assist in the initial diagnostic process, particularly in areas with limited access to specialized medical personnel.

Table 1. Diagnosis of Diseases in the Female Reproductive System

Disease Code	Disease
P01	Ovarian Cysts
P02	Uterine Fibroids
P03	Endometriosis
P04	Reproductive Tract Infections
P05	Cervical Cancer

Table 1 presents a list of diseases related to the female reproductive system, each assigned a unique code for easy identification. There are five types of diseases: Ovarian Cysts (P01), Uterine Fibroids (P02), Endometriosis (P03),

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Reproductive Tract Infections (P04), and Cervical Cancer (P05). This classification aims to support the diagnostic process in expert systems or medical analyses related to women's reproductive health.

Table 2. Symptoms of Female Reproductive System Diseases

Symptom Code	Symptom	P01	P02	P03	P04	P05	Expertise Value
G01	Lower abdominal pain	*	*	*	*	*	1.0
G02	Irregular menstruation	*	*	*	-	*	0.85
G03	Bloated stomach	*	-	*	-	-	0.5
G04	Frequent urination	*	*	-	-	-	0.5
G05	Pain during sexual intercourse	*	*	*	*	*	1.0
G06	Heavy bleeding during menstruation	-	*	*	-	*	0.7
G07	Unpleasant-smelling vaginal discharge	-	-	-	*	*	0.5
G08	Fever	-	-	-	*	-	0.4
G09	Nausea or vomiting	*	-	-	*	-	0.5
G10	Back pain	*	*	*	-	*	0.85
G11	Excessive fatigue	-	-	*	-	*	0.5
G12	Abnormal enlargement of the abdomen	*	*	-	-	-	0.5
G13	Bleeding after sexual intercourse	-	-	-	-	*	0.4
G14	Itching in the genital area	-	-	-	*	-	0.4
G15	Loss of appetite	*	-	*	*	*	0.85
G16	Pain when urinating	-	-	-	*	*	0.5
G17	Constipation or difficulty defecating	*	*	-	-	-	0.5
G18	Pain during menstruation (dysmenorrhea)	*	*	*	-	*	0.85
G19	Increased menstrual blood volume	-	*	*	-	*	0.7
G20	Feeling of fullness in the stomach or pelvis	*	*	*	-	-	0.7
G21	Unexplained weight loss	-	-	-	-	*	0.4
G22	Unpleasant odor after menstruation	-	-	-	*	*	0.5
G23	Pain when sitting or walking	-	-	*	-	-	0.4
G24	Bleeding outside the menstrual cycle	-	*	*	-	*	0.7
G25	Pain in the inner thigh	-	*	*	-	*	0.7

Table 2 presents a list of symptoms associated with various diseases of the female reproductive system. Each symptom is assigned a specific code (G01–G25) and linked to five types of diseases (P01–P05), marked with an asterisk (*) if the symptom appears in the related disease. Additionally, the table includes an Expertise Value, which represents the level of confidence experts have in the relevance of each symptom to the diagnosis of the disease, with values ranging from 0.4 to 1.0.

Table 3. Percentage Values of Certainty

Percentage Level	Probability Value	CF Value Range
0% - 50%	Slightly likely	0.0 – 0.5
51% - 79%	Possible	0.51 – 0.79
80% - 99%	Most likely	0.8 – 0.99
100%	Very confident	1.0

Table 3 shows the classification of certainty levels in the form of percentages, probability values, and certainty factor (CF) value ranges. CF values between 0.0 and 0.5 are categorized as “Low probability,” while values between 0.51 and 0.79 are considered “Probable.” If the CF value is between 0.8 and 0.99, it is categorized as “High Likelihood,” and a CF value of 1.0 indicates a “Very Certain” condition. This table serves as a guide for interpreting the level of confidence in the diagnostic results of the expert system.

Table 4. Data on Symptoms Experienced by Users

Symptom Code	Symptom	User Value
G01	Lower abdominal pain	0.8
G02	Irregular menstruation	1.0
G05	Pain during sexual intercourse	0.7
G06	Heavy bleeding during menstruation	0.6
G07	Unpleasant-smelling vaginal discharge	0.9
G10	Back pain	0.85
G13	Bleeding after sexual intercourse	0.6
G15	Loss of appetite	0.5
G16	Pain when urinating	0.75
G18	Pain during menstruation (dysmenorrhea)	0.95

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Table 4 presents data on symptoms experienced by users, consisting of 10 different symptoms coded (G01–G18) along with users' confidence levels for each symptom. These values represent the level of intensity or certainty felt regarding the symptom, with a range from 0.5 to 1.0. For example, the symptom irregular menstruation (G02) has the highest value of 1.0, indicating full confidence from the user regarding that symptom. This data serves as an important input in the diagnostic process using expert system methods, such as the Certainty Factor, to determine the likelihood of the type of disease being suffered.

3.2 Application of Method

3.2.1 Application of the Certainty Factor Method

In the Certainty Factor method, each symptom experienced by the user is associated with a certainty weight from an expert. Then, the certainty level is calculated based on a combination of the expert's weight and the symptoms experienced. The final result of this calculation is the confidence value for each possible disease. The following are the calculation steps using the Certainty Factor method.

a. Ovarian Cysts

Lower abdominal pain : $CF_1 = 1.0 * 0.8 = 0.8$
Irregular menstruation : $CF_2 = 0.85 * 1.0 = 0.85$
Pain during sexual intercourse : $CF_3 = 1.0 * 0.7 = 0.7$
Back pain : $CF_4 = 0.85 * 0.85 = 0.723$
Loss of appetite : $CF_5 = 0.85 * 0.5 = 0.425$
Pain during menstruation (dysmenorrhea) : $CF_6 = 0.85 * 0.95 = 0.808$

Next, calculation of the Certainty Factor combination.

$CF_{comb1} = 0.8 + 0.85 * (1 - 0.8) = 0.97$
$CF_{comb2} = 0.97 + 0.7 * (1 - 0.97) = 0.991$
$CF_{comb3} = 0.991 + 0.723 * (1 - 0.991) = 0.9975$
$CF_{comb4} = 0.9975 + 0.425 * (1 - 0.9975) = 0.9986$
$CF_{comb5} = 0.9986 + 0.808 * (1 - 0.9986) = 0.9997$

b. Uterine Fibroids

Lower abdominal pain : $CF_1 = 1.0 * 0.8 = 0.8$
Irregular menstruation : $CF_2 = 0.85 * 1.0 = 0.85$
Pain during sexual intercourse : $CF_3 = 1.0 * 0.7 = 0.7$
Heavy bleeding during menstruation : $CF_4 = 0.7 * 0.6 = 0.42$
Back pain : $CF_5 = 0.85 * 0.85 = 0.72$
Pain during menstruation (dysmenorrhea) : $CF_6 = 0.85 * 0.95 = 0.81$

Next, calculation of the Certainty Factor combination.

$CF_{comb1} = 0.8 + 0.85 * (1 - 0.8) = 0.97$
$CF_{comb2} = 0.97 + 0.7 * (1 - 0.97) = 0.991$
$CF_{comb3} = 0.991 + 0.42 * (1 - 0.991) = 0.995$
$CF_{comb4} = 0.995 + 0.72 * (1 - 0.995) = 0.997$
$CF_{comb5} = 0.997 + 0.81 * (1 - 0.997) = 0.9994$

c. Endometriosis

Lower abdominal pain : $CF_1 = 1.0 * 0.8 = 0.8$
Irregular menstruation : $CF_2 = 0.85 * 1.0 = 0.85$
Pain during sexual intercourse : $CF_3 = 1.0 * 0.7 = 0.7$
Heavy bleeding during menstruation : $CF_4 = 0.7 * 0.6 = 0.42$
Back pain : $CF_5 = 0.85 * 0.85 = 0.723$
Loss of appetite : $CF_6 = 0.85 * 0.5 = 0.425$
Pain during menstruation (dysmenorrhea) : $CF_7 = 0.85 * 0.95 = 0.808$

Next, calculation of the Certainty Factor combination.

$CF_{comb1} = 0.8 + 0.85 * (1 - 0.8) = 0.97$
$CF_{comb2} = 0.97 + 0.7 * (1 - 0.97) = 0.991$
$CF_{comb3} = 0.991 + 0.42 * (1 - 0.991) = 0.9948$
$CF_{comb4} = 0.9948 + 0.723 * (1 - 0.9948) = 0.9986$
$CF_{comb5} = 0.9986 + 0.425 * (1 - 0.9986) = 0.9992$
$CF_{comb6} = 0.9992 + 0.808 * (1 - 0.9992) = 0.9998$

d. Reproductive Tract Infections

Lower abdominal pain : $CF_1 = 1.0 * 0.8 = 0.8$
Pain during sexual intercourse : $CF_2 = 1.0 * 0.7 = 0.7$
Unpleasant-smelling vaginal discharge : $CF_3 = 0.5 * 0.9 = 0.45$
Loss of appetite : $CF_4 = 0.85 * 0.5 = 0.425$
Pain when urinating : $CF_5 = 0.5 * 0.75 = 0.375$

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Next, calculation of the Certainty Factor combination.
$CF_{comb1} = 0.8 + 0.7 * (1 - 0.8) = 0.94$
$CF_{comb2} = 0.94 + 0.45 * (1 - 0.94) = 0.967$
$CF_{comb3} = 0.967 + 0.425 * (1 - 0.967) = 0.981$
$CF_{comb4} = 0.981 + 0.375 * (1 - 0.981) = 0.9881$

e. Cervical Cancer

Lower abdominal pain : $CF_1 = 1.0 * 0.8 = 0.8$
Irregular menstruation : $CF_2 = 0.85 * 1.0 = 0.85$
Pain during sexual intercourse : $CF_3 = 1.0 * 0.7 = 0.7$
Heavy bleeding during menstruation : $CF_4 = 0.7 * 0.6 = 0.42$
Unpleasant-smelling vaginal discharge : $CF_5 = 0.5 * 0.9 = 0.45$
Back pain : $CF_6 = 0.85 * 0.85 = 0.72$
Bleeding after sexual intercourse : $CF_7 = 0.4 * 0.6 = 0.24$
Loss of appetite : $CF_8 = 0.85 * 0.5 = 0.425$
Pain when urinating : $CF_9 = 0.5 * 0.75 = 0.375$
Pain during menstruation (dysmenorrhea) : $CF_{10} = 0.85 * 0.95 = 0.8075$

Next, calculation of the Certainty Factor combination.
$CF_{comb1} = 0.8 + 0.85 * (1 - 0.8) = 0.97$
$CF_{comb2} = 0.97 + 0.7 * (1 - 0.97) = 0.991$
$CF_{comb3} = 0.991 + 0.42 * (1 - 0.991) = 0.9948$
$CF_{comb4} = 0.9948 + 0.45 * (1 - 0.9948) = 0.9971$
$CF_{comb5} = 0.9971 + 0.72 * (1 - 0.9971) = 0.9992$
$CF_{comb6} = 0.9992 + 0.24 * (1 - 0.9992) = 0.9994$
$CF_{comb7} = 0.9994 + 0.425 * (1 - 0.9994) = 0.9997$
$CF_{comb8} = 0.9997 + 0.375 * (1 - 0.9997) = 0.9998$
$CF_{comb9} = 0.9998 + 0.8075 * (1 - 0.9998) = 0.9999$

Table 5. Hasil Perhitungan Certainty Factor

Disease Code	Disease	Nilai CF Kombinasi
P01	Ovarian Cysts	0.9997
P02	Uterine Fibroids	0.9994
P03	Endometriosis	0.9998
P04	Reproductive Tract Infections	0.9881
P05	Cervical Cancer	0.9999

Table 5 shows the results of the calculation of the combined Certainty Factor (CF) values for each disease in the female reproductive system based on the symptoms experienced by users. The CF value indicates the system's level of confidence in the diagnosis of a disease. The highest result is shown by Cervical Cancer (P05) with a CF value of 0.9999, followed by Endometriosis (P03) at 0.9998. All values fall within the “Highly Likely” to “Very Certain” categories, indicating that users are highly likely to be experiencing one of the listed diseases, particularly Cervical Cancer.

3.2.2 Application of the Dempster Shafer Method

In the Dempster Shafer method, information from each symptom is converted into a mass confidence value for the disease hypothesis. The combination process is carried out gradually between symptoms, which produces a total confidence value for each disease. The following are the calculation steps using the Dempster Shafer method.

Lower abdominal pain merupakan Symptom dari P01, P02, P03, P04, P05 dengan nilai 1.0

$M_1(P01, P02, P03, P04, P05) = 1.0$
$M_1(\theta) = 1 - 1.0 = 0$

Irregular menstruation is a symptom of P01, P02, P03, P05 with a value of 0.85.

$M_2(P01, P02, P03, P05) = 0.85$
$M_2(\theta) = 1 - 0.85 = 0.15$

Table 6. M3 Combination Rules

	M2 (P01, P02, P03, P05) 0.85	M2 (θ) 0.15
M1 (P01, P02, P03, P04, P05) 1.0	P01, P02, P03, P05 0.85	P01, P02, P03, P04, P05 0.15
M1 (θ) 0	P01, P02, P03, P05 0	θ 0

$M_3(P01, P02, P03, P04, P05) = 0.15$

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$M_3(P01, P02, P03, P05) = 0.85$
$M_3(\theta) = 0$

Pain during sexual intercourse is a symptom of P01, P02, P03, P04, P05 with a value of 1.00.

$M_4(P01, P02, P03, P04, P05) = 1.0$
$M_4(\theta) = 1 - 1.0 = 0$

Table 7. M5 Combination Rules

	M4 (P01, P02, P03, P04, P05) 1.0	M4 (θ) 0
M3 (P01, P02, P03, P04, P05) 0.15	P01, P02, P03, P04, P05 0.15	P01, P02, P03, P04, P05 0
M3 (P01, P02, P03, P05) 0.85	P01, P02, P03, P05 0.85	P01, P02, P03, P05 0
M3 (θ) 0	P01, P02, P03, P04, P05 0	θ 0

$M_5(P01, P02, P03, P04, P05) = 0.15$
$M_5(P01, P02, P03, P05) = 0.85$
$M_5(\theta) = 0$

Heavy bleeding during menstruation is a symptom of P02, P03, and P05 with a value of 0.7.

$M_6(P02, P03, P05) = 0.7$
$M_6(\theta) = 1 - 0.7 = 0.3$

Table 8. M7 Combination Rules

	M6 (P02, P03, P05) 0.7	M6 (θ) 0.3
M5 (P01, P02, P03, P04, P05) 0.15	P02, P03, P05 0.105	P01, P02, P03, P04, P05 0.045
M5 (P01, P02, P03, P05) 0.85	P02, P03, P05 0.595	P01, P02, P03, P05 0.255
M5 (θ) 0	P02, P03, P05 0	θ 0

$M_7(P01, P02, P03, P04, P05) = 0.045$
$M_7(P01, P02, P03, P05) = 0.255$
$M_7(P02, P03, P05) = 0.105 + 0.595 = 0.7$
$M_7(\theta) = 0$

Unpleasant-smelling vaginal discharge is a symptom of P04, P05 with a value of 0.5.

$M_8(P04, P05) = 0.5$
$M_8(\theta) = 1 - 0.5 = 0.5$

Table 9. M9 Combination Rules

	M8 (P04, P05) 0.5	M8 (θ) 0.5
M7 (P01, P02, P03, P04, P05) 0.045	P04, P05 0.0225	P01, P02, P03, P04, P05 0.0255
M7 (P01, P02, P03, P05) 0.255	P05 0.1275	P01, P02, P03, P05 0.1275
M7 (P02, P03, P05) 0.7	P05 0.35	P02, P03, P05 0.35
M7 (θ) 0	P04, P05 0	θ 0

$M_9(P01, P02, P03, P04, P05) = 0.0255$
$M_9(P01, P02, P03, P05) = 0.1275$
$M_9(P02, P03, P05) = 0.35$
$M_9(P04, P05) = 0.0225$
$M_9(P05) = 0.1275 + 0.35 = 0.4775$
$M_9(\theta) = 0$

Back pain is a symptom of P01, P02, P03, P05 with a value of 0.85.

$M_{10}(P01, P02, P03, P05) = 0.85$
$M_{10}(\theta) = 0.15$

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Table 10. M11 Combination Rules

	M10 (P01, P02, P03, P05) 0.85	M10 (θ) 0.15
M9 (P01, P02, P03, P04, P05) 0.0255	P01, P02, P03, P05 0.021676	P01, P02, P03, P04, P05
M9 (P01, P02, P03, P05) 0.1275	P01, P02, P03, P05 0.10838	P01, P02, P03, P05
M9 (P02, P03, P05) 0.35	P02, P03, P05 0.2975	P02, P03, P05
M9 (P04, P05) 0.0225	P05 0.01912	P04, P05
M9 (P05) 0.4775	P05	P05
M9 (θ) 0	P01, P02, P03, P05	θ 0

$M_{11}(P01, P02, P03, P04, P05) = 0.003825$
$M_{11}(P01, P02, P03, P05) = 0.021675 + 0.108375 + 0.019125 = 0.149175$
$M_{11}(P02, P03, P05) = 0.2975 + 0.0525 = 0.35$
$M_{11}(P04, P05) = 0.003375$
$M_{11}(P05) = 0.019125 + 0.405875 + 0.071625 = 0.496625$
$M_{11}(\theta) = 0$

Bleeding after sexual intercourse is a symptom of P05 with a value of 0.4.

$M_{12}(P05) = 0.4$
$M_{12}(\theta) = 1 - 0.4 = 0.6$

Table 11. M13 Combination Rules

	M12 (P05) 0.4	M12 (θ) 0.6
M11 (P01, P02, P03, P04, P05)	P05 0.00153	P01, P02, P03, P04, P05 0.002295
M11 (P01, P02, P03, P05)	P05 0.05967	P01, P02, P03, P05 0.089505
M11 (P02, P03, P05)	P05 0.14	P02, P03, P05 0.21
M11 (P04, P05)	P05 0.00135	P04, P05 0.002025
M11 (P05)	P05 0.19865	P05 0.297975
M11 (θ) 0	P05 0	θ 0

$M_{13}(P01, P02, P03, P04, P05) = 0.002295$
$M_{13}(P01, P02, P03, P05) = 0.089505$
$M_{13}(P02, P03, P05) = 0.21$
$M_{13}(P04, P05) = 0.002025$
$M_{13}(P05) = 0.00153 + 0.05967 + 0.14 + 0.00135 + 0.19865 + 0.297975 = 0.69918$
$M_{13}(\theta) = 0$

Loss of appetite is a symptom of P01, P03, P04, P05 with a value of 0.85.

$M_{14}(P01, P03, P04, P05) = 0.85$
$M_{14}(\theta) = 0.15$

Table 12. M15 Combination Rules

	M14 (P01, P03, P04, P05) 0.85	M14 (θ) 0.15
M13 (P01, P02, P03, P04, P05) 0.002295	P01, P03, P04, P05 0.00195075	P01, P02, P03, P04, P05 0.00034425
M13 (P01, P02, P03, P05) 0.089505	P01, P03, P05 0.07607925	P01, P02, P03, P05 0.01342575
M13 (P02, P03, P05) 0.21	P03, P05 0.1785	P02, P03, P05 0.0315

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M13 (P04, P05)	P04, P05	P04, P05
0.002025	0.00172125	0.00030375
M13 (P05)	P05	P05
0.69918	0.594303	0.104877
M13 (θ)	P01, P03, P04, P05	θ
0	0	0

$M_{15}(P01, P02, P03, P04, P05) = 0.00034425$
$M_{15}(P01, P02, P03, P05) = 0.01342575$
$M_{15}(P01, P03, P04, P05) = 0.00195075$
$M_{15}(P02, P03, P05) = 0.0315$
$M_{15}(P01, P03, P05) = 0.07607925$
$M_{15}(P03, P05) = 0.1785$
$M_{15}(P04, P05) = 0.00172125 + 0.00030375 = 0.002025$
$M_{15}(P05) = 0.594303 + 0.104877 = 0.69918$
$M_{15}(\theta) = 0$

Pain when urinating is a symptom of P04, P05 with a value of 0.5.

$M_{16}(P04, P05) = 0.5$
$M_{16}(\theta) = 1 - 0.5 = 0.5$

Table 13. M17 Combination Rules

	M16 (P04, P05) 0.5	M16 (θ) 0.5
M15 (P01, P02, P03, P04, P05)	P04, P05	P01, P02, P03, P04, P05
0.00034425	0.000172	0.000172
M15 (P01, P02, P03, P05)	P05	P01, P02, P03, P05
0.01342575	0.006713	0.006713
M15 (P01, P03, P04, P05)	P04, P05	P01, P03, P04, P05
0.00195075	0.000975	0.000975
M15 (P02, P03, P05)	P05	P02, P03, P05
0.0315	0.01575	0.01575
M15 (P01, P03, P05)	P05	P01, P03, P05
0.07607925	0.03804	0.03804
M15 (P03, P05)	P05	P03, P05
0.1785	0.08925	0.08925
M15 (P04, P05)	P04, P05	P04, P05
0.002025	0.001013	0.001013
M15 (P05)	P05	P05
0.69918	0.34959	0.34959
M15 (θ)	P04, P05	θ
0	0	0

$M_{17}(P01, P02, P03, P04, P05) = 0.000172$
$M_{17}(P01, P02, P03, P05) = 0.006713$
$M_{17}(P01, P03, P04, P05) = 0.000975$
$M_{17}(P02, P03, P05) = 0.015750$
$M_{17}(P01, P03, P05) = 0.038040$
$M_{17}(P03, P05) = 0.089250$
$M_{17}(P04, P05) = 0.000172 + 0.000975 + 0.001013 + 0.001013 = 0.00317$
$M_{17}(P05) = 0.006713 + 0.015750 + 0.038040 + 0.089250 + 0.349590 + 0.349590 = 0.84893$
$M_{17}(\theta) = 0$

Pain during menstruation (dysmenorrhea) is a symptom of P01, P02, P03, P05 with a value of 0.85.

$M_{18}(P01, P02, P03, P05) = 0.85$
$M_{18}(\theta) = 1 - 0.85 = 0.15$

Table 14. M19 Combination Rules

	M17 (P01, P02, P03, P05) 0.85	M17 (θ) 0.15
M17 (P01, P02, P03, P04, P05)	P01, P02, P03, P05	P01, P02, P03, P04, P05
0.000172	0.0001462	0.0000258
M17 (P01, P02, P03, P05)	P01, P02, P03, P05	P01, P02, P03, P05
0.006713	0.00570605	0.00100695

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M17 (P01, P03, P04, P05)	P01, P03, P05	P01, P03, P04, P05
0.000975	0.00082875	0.00014625
M17 (P02, P03, P05)	P02, P03, P05	P02, P03, P05
0.015750	0.0133875	0.0023625
M17 (P01, P03, P05)	P01, P03, P05	P01, P03, P05
0.038040	0.032334	0.005706
M17 (P03, P05)	P03, P05	P03, P05
0.089250	0.0758625	0.0133875
M17 (P04, P05)	P05	P04, P05
0.00317	0.0026945	0.0004755
M17 (P05)	P05	P05
0.84893	0.7215905	0.1273395
M17 (θ)	P01, P02, P03, P05	θ
0	0	0

$M_{19}(P01, P02, P03, P04, P05) = 0.0000258$
$M_{19}(P01, P02, P03, P05) = 0.0001462 + 0.00570605 + 0.00100695 = 0.00686$
$M_{19}(P01, P03, P04, P05) = 0.00014625$
$M_{19}(P01, P03, P05) = 0.00082875 + 0.032334 + 0.005706 = 0.03887$
$M_{19}(P02, P03, P05) = 0.0133875 + 0.0023625 = 0.01575$
$M_{19}(P03, P05) = 0.0758625 + 0.0133875 = 0.08925$
$M_{19}(P04, P05) = 0.0004755$
$M_{19}(P05) = 0.0026945 + 0.7215905 + 0.1273395 = 0.85162$
$M_{19}(\theta) = 0$

The highest value for the combination of symptoms in female reproductive system diseases was obtained at 0.85162 or 85%, based on the results of calculations using the Dempster Shafer method with 10 symptoms. These results indicate that the patient most likely suffers from cervical cancer, a type of female reproductive system disease.

3.2.3 Application of Bayes' Theorem Method

In this method, the initial probability of each disease is combined with the conditional probability based on the detected symptoms. This approach produces posterior probabilities, which are the likelihood of a particular disease occurring given the known symptoms. The following are the calculation steps using Bayes' theorem.

a. Determine the probability
   1. Ovarian Cysts

$$P[H]1 = \frac{1.00}{1.0+0.85+0.5+0.5+1.0+0.5+0.85+0.5+0.85+0.5+0.85+0.7} = \frac{1.00}{8.60} = 0.116$$
$$P[H]2 = \frac{0.85}{1.0+0.85+0.5+0.5+1.0+0.5+0.85+0.5+0.85+0.5+0.85+0.7} = \frac{0.85}{8.60} = 0.099$$
$$P[H]3 = \frac{0.5}{1.0+0.85+0.5+0.5+1.0+0.5+0.85+0.5+0.85+0.5+0.85+0.7} = \frac{0.5}{8.60} = 0.058$$
$$P[H]4 = \frac{0.5}{1.0+0.85+0.5+0.5+1.0+0.5+0.85+0.5+0.85+0.5+0.85+0.7} = \frac{0.5}{8.60} = 0.058$$
$$P[H]5 = \frac{1.0}{1.0+0.85+0.5+0.5+1.0+0.5+0.85+0.5+0.85+0.5+0.85+0.7} = \frac{1.0}{8.60} = 0.116$$
$$P[H]6 = \frac{0.5}{1.0+0.85+0.5+0.5+1.0+0.5+0.85+0.5+0.85+0.5+0.85+0.7} = \frac{0.5}{8.60} = 0.058$$
$$P[H]7 = \frac{0.85}{1.0+0.85+0.5+0.5+1.0+0.5+0.85+0.5+0.85+0.5+0.85+0.7} = \frac{0.85}{8.60} = 0.099$$
$$P[H]8 = \frac{0.5}{1.0+0.85+0.5+0.5+1.0+0.5+0.85+0.5+0.85+0.5+0.85+0.7} = \frac{0.5}{8.60} = 0.058$$
$$P[H]9 = \frac{0.85}{1.0+0.85+0.5+0.5+1.0+0.5+0.85+0.5+0.85+0.5+0.85+0.7} = \frac{0.85}{8.60} = 0.099$$
$$P[H]10 = \frac{0.5}{1.0+0.85+0.5+0.5+1.0+0.5+0.85+0.5+0.85+0.5+0.85+0.7} = \frac{0.5}{8.60} = 0.58$$
$$P[H]11 = \frac{0.85}{1.0+0.85+0.5+0.5+1.0+0.5+0.85+0.5+0.85+0.5+0.85+0.7} = \frac{0.85}{8.60} = 0.099$$
$$P[H]12 = \frac{0.7}{1.0+0.85+0.5+0.5+1.0+0.5+0.85+0.5+0.85+0.5+0.85+0.7} = \frac{0.7}{8.60} = 0.081$$

Similar calculations were performed for all female reproductive system diseases. The final results of the calculations for all diseases are presented in Table 15 below.

Table 15. Disease Probability Results

Ovarian Cysts		Uterine Fibroids		Endometriosis		Reproductive Tract Infections		Cervical Cancer	
Kode	Nilai	Kode	Nilai	Kode	Nilai	Kode	Nilai	Kode	Nilai
G01	0.116	G01	0.105	G01	0.097	G01	0.177	G01	0.091
G02	0.099	G02	0.089	G02	0.083	G05	0.177	G02	0.077
G03	0.058	G04	0.052	G03	0.049	G07	0.088	G05	0.091

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Ovarian Cysts		Uterine Fibroids		Endometriosis		Reproductive Tract Infections		Cervical Cancer	
Kode	Nilai	Kode	Nilai	Kode	Nilai	Kode	Nilai	Kode	Nilai
G04	0.058	G05	0.105	G05	0.097	G08	0.071	G06	0.064
G05	0.116	G06	0.073	G06	0.068	G09	0.088	G07	0.045
G09	0.058	G10	0.089	G10	0.083	G14	0.071	G10	0.077
G10	0.099	G12	0.052	G11	0.049	G15	0.150	G11	0.045
G12	0.058	G17	0.052	G15	0.083	G16	0.088	G13	0.036
G15	0.099	G18	0.089	G18	0.083	G22	0.088	G15	0.077
G17	0.058	G19	0.073	G19	0.068			G16	0.045
G18	0.099	G20	0.073	G20	0.068			G18	0.077
G20	0.081	G24	0.073	G23	0.039			G19	0.064
		G25	0.073	G24	0.068			G21	0.036
				G25	0.068			G22	0.045
								G24	0.064
								G25	0.064

b. Probability value of evidence

1. Ovarian Cysts

$\sum_{k=1}^{n} = (0.116*1.00) + (0.099*0.850) + (0.058*0) + (0.058*0) + (0.116*1.000) + (0.058*0) + (0.099*0.850) + (0.058*0) + (0.099*0.850) + (0.058*0) + (0.099*0.850) + (0.081*0) = 0.569$

$P[H|E]1 = \frac{(0.116*1.00)}{0.569} = 0.204$

$P[H|E]2 = \frac{(0.099*0.850)}{0.569} = 0.148$

$P[H|E]3 = \frac{(0.058*0)}{0.569} = 0$

$P[H|E]4 = \frac{(0.058*0)}{0.569} = 0$

$P[H|E]5 = \frac{(0.116*1.000)}{0.569} = 0.204$

$P[H|E]6 = \frac{(0.058*0)}{0.569} = 0$

$P[H|E]7 = \frac{(0.099*0.850)}{0.569} = 0.148$

$P[H|E]8 = \frac{(0.058*0)}{0.569} = 0$

$P[H|E]9 = \frac{(0.099*0.850)}{0.569} = 0.148$

$P[H|E]10 = \frac{(0.058*0)}{0.569} = 0$

$P[H|E]11 = \frac{(0.099*0.850)}{0.569} = 0.148$

$P[H|E]12 = \frac{(0.081*0)}{0.569} = 0$

$\sum_{k=1}^{n} \text{Bayes} = \big((0.204*1.0) + (0.148*0.85) + (0*0) + (0*0) + (0.204*1.0) + (0*0) + (0.148*0.85) + (0*0) + (0.148*0.099) + (0*0) + (0.148*0.099) + (0*0)\big)*100\% = 0.911$

Table 16. Results of Bayes' Theorem Calculations

Disease Code	Disease	Combined CF Value
P01	Ovarian Cysts	0.911
P02	Uterine Fibroids	0.899
P03	Endometriosis	0.892
P04	Reproductive Tract Infections	0.889
P05	Cervical Cancer	0.847

3.3 Comparison of Methods

Based on the results obtained from the three methods, there appears to be variation in the diagnosis results. The Certainty Factor and Dempster Shafer methods tend to provide results that focus on combinations of dominant symptoms, while the Bayes method relies on the initial probability proportions and the influence of each symptom.

Table 17. Comparison of Method Results

Method	Types of Diseases with the Highest Scores	Value
Certainty Factor	Cervical Cancer	0.9999
Dempster Shafer	Cervical Cancer	0,852
Teorema Bayes	Ovarian Cysts	0.911

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Table 17 shows a comparison of the results of three inference methods Certainty Factor, Dempster Shafer, and Bayes' Theorem, in diagnosing disease types based on the given symptoms. The Certainty Factor and Dempster Shafer methods both identify cervical cancer as the disease with the highest confidence value, at 0.9999 and 0.852, respectively. Meanwhile, Bayes' Theorem produces a different diagnosis, namely Ovarian Cysts, with a confidence value of 0.911. This difference indicates that diagnostic results are significantly influenced by the computational approach of each method.

4. CONCLUSION

This study has implemented and compared three inference methods, namely Certainty Factor, Dempster Shafer, and Bayes Theorem, in diagnosing female reproductive system diseases based on symptoms that appear in the expert system. The three methods are used to process symptom data that has been validated by experts and produce diagnostic output with a certain confidence value. The test results show that the Certainty Factor method produces the highest confidence value for the diagnosis of Cervical Cancer of 0.9999. The Dempster Shafer method also indicates Cervical Cancer as the most likely disease, although with a lower confidence value of 0.852. Meanwhile, the Bayes Theorem method produces a different diagnosis, namely Ovarian Cysts, with a confidence level of 0.911. The difference in diagnostic results shows that each method has a different approach to calculation and uncertainty representation. Certainty Factor relies more on expert values and combining confidence based on specified rules, while Dempster Shafer combines evidence through set theory and confidence functions. Bayes' Theorem uses conditional probability and prior probability distributions to determine the likelihood of a disease occurring. Therefore, while all methods are capable of providing a diagnosis, the choice of inference method used in an expert system significantly determines the final outcome. Certainty Factor and Dempster-Shafer tend to produce consistent diagnoses, while Bayes' Theorem can yield different results depending on the prior probability used. Therefore, the choice of method must consider the system's needs, data characteristics, and the preferences of the user or medical expert.

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