Jurnal Teknik Informatika (JUTIF)
Vol. 5, No. 3, June 2024, pp. 891-901

DOI: https://doi.org/10.52436/1.jutif.2024.5.3.2021
p-ISSN: 2723-3863
e-ISSN: 2723-3871

EXPERT SYSTEM WITH DEMPSTER-SHAFER METHOD FOR EARLY IDENTIFICATION OF DISEASES DUE TO COMPLICATIONS SYSTEMIC INFLAMMATORY RESPONSE SYNDROME

Adanti Wido Paramadini[1], Dasril Aldo[*2], M. Yoka Fathoni[3], Yohani Setiya Rafika Nur[4], Dading Qolbu Adi[5]

[1]Biomedical Engineering, Faculty of Telecommunications and Electronics Engineering, Institut Teknologi Telkom Purwokerto, Indonesia
[2,4,5]Informatics Engineering, Faculty of Informatics, Institut Teknologi Telkom Purwokerto, Indonesia
[3]Information Technology, University Kuala Lumpur, Malaysia
Email: [1]adanti@ittelkom-pwt.ac.id, [2]dasril@ittelkom-pwt.ac.id, [3]fathoni.yoka@s.unikl.edu.my, [4]20102075@ittelkom-pwt.ac.id

(Article received: April 28, 2024; Revision: May 14, 2024; published: June 05, 2024)

Abstract

Systemic Inflammatory Response Syndrome (SIRS) is a generalized inflammatory condition, triggered by various factors such as infection or trauma, which can lead to serious complications if not treated quickly. This condition is characterized by symptoms such as fever or hypothermia, tachycardia, tachypnea, and changes in white blood cell count. Complications that can arise from SIRS include Acute Respiratory Distress Syndrome (ARDS), which results in fluid in the alveoli and requires mechanical ventilation; acute encephalopathy, which leads to brain dysfunction; Asidosis Metabolik, indicating liver damage; hemolysis, which results in the breakdown of red blood cells; and Deep Vein Thrombosis (DVT), which is at risk of causing pulmonary embolism. To overcome this diagnostic challenge, this study implements the Dempster-Shafer method in an expert system, where it allows the aggregation and combination of various sources of evidence to produce degrees of belief and degrees of plausibility for each diagnostic hypothesis. By accounting for uncertainties and contradictions in the data, the system improves diagnostic accuracy through dynamically weighting and updating beliefs based on available evidence. This process allows early and accurate identification of SIRS complications, supporting appropriate medical intervention. System evaluation showed diagnostic accuracy of 93%, confirming the potential of expert systems in supporting rapid and precise clinical decision-making in managing SIRS complications.

Keywords: *Clinical Data Analysis, Dempster-Shafer, Expert System, Medical Decision Support System, Systemic Inflammatory Response Syndrome (SIRS).*

1. INTRODUCTION

In the modern era, attention is paid to improving the quality of health services, especially in the diagnosis and management of critical conditions [1] like Systemic Inflammatory Response Syndrome (SIRS), has experienced significant growth. SIRS is a condition that can trigger an inflammatory response throughout the body, triggered by various factors such as infection, trauma, or other serious illnesses [2]. Because it can lead to fatal complications such as sepsis or sepsis shock, an in-depth understanding of SIRS and its complications is important in contemporary medical practice [3] [4].

Early and accurate identification of complications associated with SIRS, such as Acute Respiratory Distress Syndrome (ARDS), acute encephalopathy, Metabolic Acidosis, hemolysis, and Deep Vein Thrombosis (DVT), is crucial in reducing morbidity and mortality [5] [6] [7]. Because early symptoms are often nonspecific, these diagnostic challenges require innovative approaches to early detection and effective management. In this context, the role of information technology, especially expert systems, becomes very relevant to support appropriate clinical decisions [8].

The Dempster-Shafer method, known for its approach to treating uncertainty and blending evidence from multiple sources, offers promising solutions in the development of expert systems for medical diagnosis [9]. Through the application of this theory, the system can accommodate and analyze a wide range of clinical data, improve predictive ability and support the medical decision-making process more accurately. Thus, the integration of the Dempster-Shafer method in expert systems opens up new avenues for efficient and effective diagnostic improvements [10].

This research aims to develop an expert system that utilizes the Dempster-Shafer method for early identification of diseases caused by complications of SIRS. Through this approach, it is expected to obtain more accurate diagnostic results, provide appropriate therapeutic recommendations, and overall improve

the quality of patient care. This review explores the system's ability to integrate clinical data and applications of Dempster-Shafer theory to achieve a high level of diagnostic accuracy.

Previous research in the last decade on the Dempster-Shafer method has been successfully implemented in various studies to develop expert systems in the medical field, which show their effectiveness in disease diagnostics [11]. For example, a study in 2022 used Dempster-Shafer to detect early Diabetes Mellitus with an accuracy of 88.5% [12], while in 2021, another study successfully applied it in the diagnosis of infectious diseases, achieving a predictive accuracy of 88.5% [13]. In addition, research in 2023 showed its use in the diagnosis of Parkinson's disease with 94% accuracy [14], and in the same year, Dempster-Shafer was successfully used to detect Flash Damage with equally impressive accuracy [15]. Finally, in 2023, a study applying Dempster-Shafer to early identification of diseases in onion plants [16], reinforces the critical role of technology in supporting fast and accurate clinical decisions. This success confirms Dempster-Shafer's great potential in the development of efficient, evidence-based diagnostic aids in the medical environment.

As a first step in achieving the objectives of this study, an expert system evaluation was carried out using real data from patients suffering from complications of SIRS. This approach is expected to validate the reliability of the Dempster-Shafer method in managing clinical information uncertainty and optimizing the diagnostic process. This evaluation is an important part in the research process aimed at strengthening the knowledge base and improving inference mechanisms, thus contributing to the improvement of the quality of health care of patients with SIRS and related complications.

This research makes an important contribution to the development of expert systems utilizing the Dempster-Shafer method, providing substantial improvements in the medical diagnostic process particularly in identifying complications of Systemic Inflammatory Response Syndrome (SIRS). The implementation of this system offers an advanced framework for ambiguous or incomplete information processing, enabling more accurate and rapid diagnosis by combining evidence from multiple clinical data sources. With a focus on improving diagnostic accuracy, this research not only enriches the science in the medical application of the Dempster-Shafer method, but also sets the basis for the use of this technology in other similar medical conditions. This opens up wider opportunities for exploration and adaptation of these expert systems across multiple disciplines, driving innovation in medical decision-making approaches and improving the quality of health interventions globally.

2. RESEARCH METHODS

In this study, the expert system is used as a theoretical basis to develop sophisticated and accurate diagnostic tools in identifying complications of Systemic Inflammatory Response Syndrome (SIRS). The expert system, which is an application of artificial intelligence [17], leverages the broad and in-depth knowledge of experts in the medical field to simulate clinical decision-making [18]. The main components of this expert system include a knowledge base containing data, rules, and models [19] relating to SIRS and its complications, as well as inference engines that use the Dempster-Shafer method to process and analyze data. Through the process of inference, this system is able to integrate various sources of information and assess the degree of confidence or belief in certain diagnostic hypotheses [20]. In addition, this expert system is equipped with an explanatory mechanism that allows users to understand the logic behind each resulting conclusion, increasing transparency and trust in the system [21]. The intuitive user interface facilitates interaction between the user and the system, allowing input of clinical data and receipt of diagnostic recommendations. By adopting this approach, the study aims to create diagnostic tools that not only improve accuracy and efficiency in identifying complications of SIRS but also facilitate more informative and evidence-based clinical decision making.

Dempster-Shafer is a mathematical framework for uncertainty processing that allows combining evidence from multiple sources to produce levels of confidence and plausibility. Unlike classical probability, this theory does not require the assignment of definite probabilities, so it is suitable for situations where information is incomplete or partial. In this theory, the mass function of confidence is allocated to each element of the set of forces, representing all possible hypotheses. The merging of proofs is done through Dempster's rule, which is a mathematical process for combining separate belief mass functions to obtain a more comprehensive picture of the actual state. This makes Dempster-Shafer theory particularly relevant for applications such as diagnostic expert systems, where uncertainty and partial information often have to be managed and interpreted.

If it is known that X is a subset of q with m1 as its density function, and Y is also a subset of q with m2 as its density function, then a combination function m1 and m2 as m3 can be formed, shown in the following equation:

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

In general, Dempster Shafer's theory is written in intervals [Belief, Plausibility] [22]. Belief (bell) is a measure of the power of evidence in support of a set of propositions. If it is 0 it indicates that there is no

evidence, and if it is 1 it indicates certainty. Plausibility (Pls) is denoted as:

$$Pls(X) = 1 - Bel(X) \quad (2)$$

The belief function can also be formulated as follows:

$$Bel(X) = \sum_{Y \in X} m(Y) \quad (3)$$

Furthermore, plausibility is denoted as:

$$Pls(X) = 1 - Bel(X) = 1 - \sum_{Y \in X} m(X) \quad (4)$$

The following algorithm of the Dempster-Shfer method is shown in Figure 1.

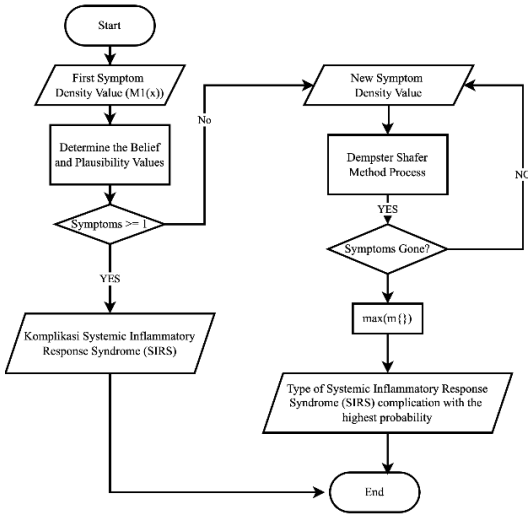


Figure 1. Dempster-Shfer Method Flowchart

Further steps in the methodology of this study are depicted in Figure 2.

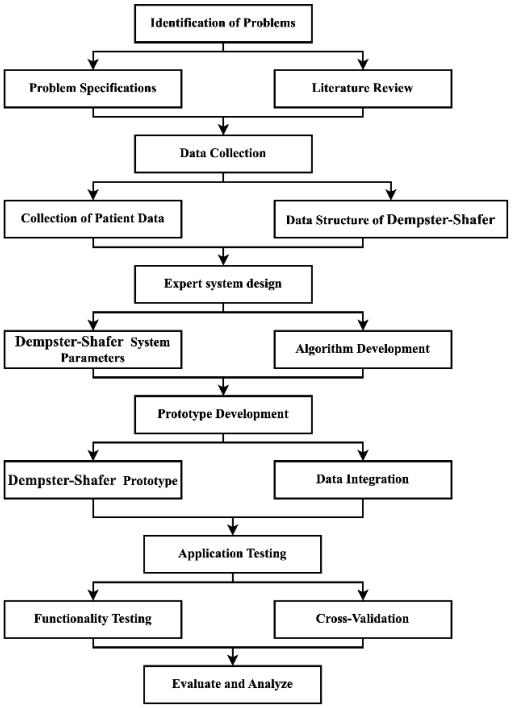


Figure 2. Stages of Research

The following is an explanation of research methodology in Figure 3 arranged based on the sequence of activities that occur at each stage:

1. Identification of Problems:
   a. Problem Specifications: Researchers determine and detail research problems, determine the scope and limits to be addressed.
   b. Literature Review: Conduct a comprehensive literature review to identify what is already known about the problem and what still needs further research.
2. Data Collection:
   a. Collection of Patient Data: Collect data from patients experiencing SIRS and related complications, including demographic, clinical, and laboratory outcome data.
   b. Data Structure of CBR: Build a data structure for Case-Based Reasoning, which will store and manage historical cases as part of the machine learning process.
3. Expert System Design:
   a. Dempster-Shafer System Parameters: Sets parameters for the Dempster-Shafer model to be used to manage uncertainty and determine trust in expert systems.
   b. Algorithm Development: Design and develop algorithms that will be used by the system to process and analyze data.
4. Prototype Development:
   a. Dempster-Shafer Prototype: Build prototypes of expert systems that integrate Dempster-Shafer theory to be tested under controlled conditions.
   b. Data Integration: Input and combine all collected data into the system to enable data analysis and processing.
5. Application Testing:
   a. Functionality Testing: Check and test every function of the expert system to ensure that everything is operating as expected.
   b. Cross-Validation: Use cross-validation methods to evaluate system reliability and accuracy with datasets independent of the data used for system training.
6. Evaluate and Analyze:
   After the expert system is tested, an evaluation and analysis stage is carried out to review the performance of the system and make conclusions about its effectiveness in diagnosing SIRS complications.

Each of the above stages involves a series of activities designed to build robust, accurate, and reliable expert systems to detect complications associated with SIRS.

3. RESULTS AND DISCUSSION

3.1. Research Data

The analyzed research data is a comprehensive collection of clinical information from patients diagnosed with complications of SIRS, including data on symptoms, diseases and relationships between disease and symptoms, shown in Table 1.

Table 1. Disease

No	Code	Disease Name
1	AR	Acute Respiratory Distress Syndrome
2	EA	Acute Encephalopathy
3	AM	Asidosis Metabolik
4	HE	Hemolisis
5	DV	Deep Vein Thrombosis

Table 1 shows five types of diseases that will be processed in this study. Furthermore, the overall symptom data will be displayed in Table 2.

Table 2. Symptom

No	Code	Symptoms
1	S01	Shortness and rapid breathing
2	S02	Shortness of breath
3	S03	Low blood pressure (hipotensi)
4	S04	The body feels very tired
5	S05	Excessive cold sweat
6	S06	Bluish lips or nails (cyanosis)
7	S07	Chest pain
8	S08	Increased heart rate (takikardia)
9	S09	Cough
10	S10	Fever
11	S11	Headache or dizziness
12	S12	Dazze
13	S13	Loss of consciousness
14	S14	Seizures
15	S15	Tremor
16	S16	Difficulty swallowing
17	S17	Memory loss
18	S18	Difficulty focusing and concentrating
19	S19	Easy drowsiness
20	S20	The eyes move uncontrollably
21	S21	Speech disorders
22	S22	Nausea and vomiting
23	S23	Loss of appetite
24	S24	Sakit kuning
25	S25	Bad breath smells like a fruity scent
26	S26	Pale skin
27	S27	Dark urine
28	S28	The stomach feels uncomfortable due to enlarged spleen and liver organs
29	S29	Limbs with DVT feel warm
30	S30	Pain that worsens when bending the legs
31	S31	Swelling of one of the limbs, especially in the calf
32	S32	Cramps that usually start in the calves, especially at night
33	S33	Changes in leg color to pale, red, or darker

After knowing the disease and symptoms, then the reality between symptoms and diseases will be displayed, in Table 3.

Table 3. Relation of Symptoms and Disease

No	Symptoms	AR	EA	AM	HE	DV	Weights
1	S01	*		*			0.16
2	S02	*				*	0.08
3	S03	*					0.05
4	S04	*			*		0.07
5	S05	*					0.09
6	S06	*					0.12
7	S07	*				*	0.07
8	S08	*		*	*	*	0.06
9	S09	*					0.04
10	S10	*			*		0.06
11	S11	*		*	*	*	0.08
12	S12	*	*	*			0.12
13	S13		*				0.2
14	S14		*				0.06
15	S15		*				0.09
16	S16		*				0.13
17	S17		*	*			0.06
18	S18		*				0.2
19	S19		*				0.14
20	S20			*			0.06
21	S21			*			0.1
22	S22			*	*		0.13
23	S23			*			0.23
24	S24				*		0.18
25	S25				*		0.23
26	S26				*		0.19
27	S27					*	0.14
28	S28					*	0.21
29	S29					*	0.18
30	S30					*	0.08
31	S31					*	0.1

Table 3 presents the relationship between various symptoms and five diseases that are complications of Systemic Inflammatory Response Syndrome (SIRS), that is Acute Respiratory Distress Syndrome (AR), Acute Encephalopathy (EA), Asidosis Metabolik (AM), Hemolisis (HE), and Deep Vein Thrombosis (DV). Each row represents a specific symptom, denoted by a unique code (e.g., S01, S02, etc.), and each column after the symptom column represents one of the five diseases. In this table, an asterisk (*) used to show the relationship between symptoms and certain diseases. If a cell in the table is filled with an asterisk, this indicates that the symptom could be an indicator of the disease in question.

Some symptoms are more specific to a particular disease, while others are more general and can be found in some diseases. The presence or absence of a particular symptom in relation to the disease can help medical professionals in making a more precise diagnosis.

3.2. Inference Engine

In an expert system, the inference engine begins its process by aligning the facts stored in the knowledge base with predefined rules. This matching helps in systematically applying the rules based on the facts available in the knowledge base.

A. Selecting Symptoms and Determining the Weight of Each Symptom

The stages of selecting symptoms that appear in patients, each symptom will be given a weight based on table 3, where if the answer of the YES user will be given a weight, if NO eating will have a weight of 0, Can be shown in Table 4.

DOI: https://doi.org/10.52436/1.jutif.2024.5.3.2021
p-ISSN: 2723-3863
e-ISSN: 2723-3871

Tabel 4. Patient Constellations

Code	Symptoms	Answer	Weights
S01	Shortness and rapid breathing	YES	0.16
S02	Shortness of breath	YES	0.08
S03	Low blood pressure (hipotensi)	YES	0.05
S04	The body feels very tired	YES	0.07
S05	Excessive cold sweat	YES	0.09
S06	Bluish lips or nails (cyanosis)	NO	0
S07	Chest pain	NO	0
S08	Increased heart rate (takikardia)	YES	0.06
S09	Cough	NO	0
S10	Fever	YES	0.06
S11	Headache or dizziness	YES	0.08
S12	Dazze	YES	0.12
S13	Loss of consciousness	NO	0
S14	Seizures	NO	0
S15	Tremor	NO	0
S16	Difficulty swallowing	NO	0
S17	Memory loss	NO	0
S18	Difficulty focusing and concentrating	NO	0
S19	Easy drowsiness	NO	0
S20	The eyes move uncontrollably	NO	0
S21	Speech disorders	NO	0
S22	Nausea and vomiting	NO	0
S23	Loss of appetite	NO	0
S24	Jaundice	NO	0
S25	Bad breath smells like a fruity scent	NO	0
S26	Pale skin	NO	0
S27	Dark urine	NO	0
S28	The stomach feels uncomfortable due to enlarged spleen and liver organs	NO	0
S29	Limbs with DVT feel warm	NO	0
S30	Pain that worsens when bending the legs	NO	0
S31	Swelling of one of the limbs, especially in the calf	NO	0
S32	Cramps that usually start in the calves, especially at night	NO	0
S33	Changes in leg color to pale, red, or darker	NO	0

RULE 1 = IF S01 AND S02 AND S03 AND S04 AND S05 AND S07 AND S08 AND S09 AND S10 AND S11 AND S12 THEN AR
RULE 2 = IF S12 AND S13 AND S14 AND S15 AND S16 AND S18 AND S19 THEN EA
RULE 3 IF = IF S01 AND S08 AND S11 AND S12 AND S17 AND S20 AND S21 AND S22 AND S23 THEN AM
RULE 4 = IF S04 AND S08 AND S10 AND S11 AND S22 AND S24 AND S25 AND S26 THEN HE
RULE 5 = IF S02 AND S07 AND S08 AND S11 AND S27 AND S28 AND S29 AND S30 AND S31 THEN DV

B. Rule Execution Process

Execution of RULE 1 for AR disease

RULE 1 = IF S01 AND S02 AND S03 AND S04 AND S05 AND S07 AND S08 AND S09 AND S10 AND S11 AND S12 THEN AR

S01 (Yes = 0.16)

Then : $M_1\{P_1\} = 0.16$

$M_1\{\Theta\} = 1 - 0.16 = 0.84$

S02 (Yes = 0.08)

Then : $M_2\{P_2\} = 0.08$

$M_2\{\Theta\} = 1 - 0.08 = 0.92$

Following this, the fresh density metric for the given combination will be determined, referred to as M_3, as outlined below:

	$M_2\{P_2\} = 0.08$	$M_2\{\Theta\} = 0.92$
$M_1\{P_1\} = 0.16$	0.0128	0.1472
$M_1\{\Theta\} = 0.84$	0.0672	0.7728

$$M_3\{P_3\} = \frac{0.0128 + 0.1472 + 0.0672}{1-0} = 0.2272$$

$$M_3\{\Theta\} = \frac{0.7728}{1-0} = 0.7728$$

S03 (Yes = 0.05)

Then : $M_4\{P_4\} = 0.05$

$M_4\{\Theta\} = 1 - 0.05 = 0.95$

Following this, the fresh density metric for the given combination will be determined, referred to as M_5, as outlined below:

	$M_4\{P_4\} = 0.05$	$M_4\{\Theta\} = 0.95$
$M_3\{P_3\} = 0.227$	0.0114	0,2158
$M_3\{\Theta\} = 0.7728$	0.0386	0,7342

$$M_5\{P_5\} = \frac{0.0114+0.2158+0.0386}{1-0} = 0,2658$$

$$M_5\{\Theta\} = \frac{0.7342}{1-0} = 0.7342$$

S04 (Yes = 0.07)

Then : $M_6\{P_6\} = 0.07$

$M_6\{\Theta\} = 1 - 0.07 = 0.93$

Following this, the fresh density metric for the given combination will be determined, referred to as M_7, as outlined below:

	$M_6\{P_6\} = 0.07$	$M_6\{\Theta\} = 0.93$
$M_5\{P_5\} = 0.2658$	0.0186	0.2472
$M_5\{\Theta\} = 0.7342$	0.0514	0.6828

$$M_7\{P_7\} = \frac{0.0186+0.2472+0.0514}{1-0} = 0.3172$$
$$M_7\{\Theta\} = \frac{0.6828}{1-0} = 0.6828$$

S05 (Yes = 0.09)

Then : $M_8\{P_8\} = 0.09$

$M_8\{\Theta\} = 1 - 0.05 = 0.91$

Following this, the fresh density metric for the given combination will be determined, referred to as M_9, as outlined below:

	$M_8\{P_8\} = 0.09$	$M_8\{\Theta\} = 0.91$
$M_7\{P_7\} = 0.3172$	0.0285	0.2887
$M_7\{\Theta\} = 0.6828$	0.0614	0.6213

$$M_9\{P_9\} = \frac{0.0285+0.2887+0.0614}{1-0} = 0.3787$$
$$M_9\{\Theta\} = \frac{0.6213}{1-0} = 0.6213$$

S08 (Yes = 0.06)

Then : $M_{10}\{P_{10}\} = 0.06$

$M_{10}\{\Theta\} = 1 - 0.06 = 0.94$

Following this, the fresh density metric for the given combination will be determined, referred to as M_{11}, as outlined below:

	$M_{10}\{P_{10}\} = 0.06$	$M_{10}\{\Theta\} = 0.94$
$M_9\{P_9\} = 0.3786$	0.0227	0.3559
$M_9\{\Theta\} = 0.6213$	0.0373	0.5840

$$M_{11}\{P_{11}\} = \frac{0.0227+0.3559+0.0373}{1-0} = 0{,}4159$$
$$M_{11}\{\Theta\} = \frac{0.5840}{1-0} = 0.5840$$

S10 (Yes = 0.06)

Then : $M_{12}\{P_{12}\} = 0.06$

$M_{12}\{\Theta\} = 1 - 0.06 = 0.94$

Following this, the fresh density metric for the given combination will be determined, referred to as M_{13}, as outlined below:

	$M_{12}\{P_{12}\} = 0.06$	$M_{12}\{\Theta\} = 0.94$
$M_{11}\{P_{11}\} = 0.4159$	0.0249	0.3910
$M_{11}\{\Theta\} = 0.5840$	0.0350	0.5489

$$M_{13}\{P_{13}\} = \frac{0.0249+0.3910+0.0350}{1-0} = 0.4510$$
$$M_{13}\{\Theta\} = \frac{0.5489}{1-0} = 0.5489$$

S11 (Yes = 0.08)

Then : $M_{14}\{P_{14}\} = 0.08$

$M_{14}\{\Theta\} = 1 - 0.08 = 0.92$

Following this, the fresh density metric for the given combination will be determined, referred to as M_{15}, as outlined below:

	$M_{14}\{P_{14}\} = 0.08$	$M_{14}\{\Theta\} = 0.92$
$M_{13}\{P_{13}\} = 0.4510$	0.0361	0.4149
$M_{13}\{\Theta\} = 0.5489$	0.0439	0.5050

$$M_{15}\{P_{15}\} = \frac{0.0361+0.4149+0.0439}{1-0} = 0.4949$$
$$M_{15}\{\Theta\} = \frac{0.5050}{1-0} = 0.5050$$

S12 (Yes = 0.12)

Then : $M_{16}\{P_{16}\} = 0.12$

$M_{16}\{\Theta\} = 1 - 0.12 = 0.88$

Following this, the fresh density metric for the given combination will be determined, referred to as M_{17}, as outlined below:

	$M_{14}\{P_{14}\} = 0.12$	$M_{14}\{\Theta\} = 0.88$
$M_{15}\{P_{15}\} = 0.4949$	0.0594	0.4355
$M_{15}\{\Theta\} = 0.5050$	0.0606	0.4444

$$M_{17}\{P_{17}\} = \frac{0.0593+0.4355+0.06060}{1-0} = 0.5555$$
$$M_{17}\{\Theta\} = \frac{0.4445}{1-0} = 0.4445$$

From the calculation above, the value of the risk density of AR or Acute Respiratory Distress Syndrome is 0.5555.

Execution of RULE 2 for EA disease

RULE 2 = IF S12 AND S13 AND S14 AND S15 AND S16 AND S18 AND S19 THEN EA

S12 (Yes = 0.12)

Then : $M_1\{P_1\} = 0.12$

$M_1\{\Theta\} = 1 - 0.12 = 0.88$

From the calculation above, the density value of risk of AR disease or Acute Encephalopathy is as high as 0.12

Execution of RULE 3 for AM disease

RULE 3 IF = IF S01 AND S08 AND S11 AND S12 AND S17 AND S20 AND S21 AND S22 AND S23 THEN AM

S01 (Yes = 0.16)

Then : $M_1\{P_1\} = 0.16$

$M_1\{\Theta\} = 1 - 0.16 = 0.84$

S08 (Yes = 0.06)

Then : $M_2\{P_2\} = 0.06$

$M_2\{\Theta\} = 1 - 0.06 = 0.94$

Following this, the fresh density metric for the given combination will be determined, referred to as M_3, as outlined below:

	$M_2\{P_2\} = 0.06$	$M_2\{\Theta\} = 0.94$
$M_1\{P_1\} = 0.16$	0.0096	0.1504
$M_1\{\Theta\} = 0.84$	0.0504	0.7896

$M_3\{P_3\} = \frac{0.0096+0,1504+0.0504}{1-0} = 0.2104$

$M_3\{\Theta\} = \frac{0.7728}{1-0} = 0.7896$

S11 (Yes = 0.08)

Then : $M_4\{P_4\} = 0.08$

$M_4\{\Theta\} = 1 - 0.08 = 0.92$

Following this, the fresh density metric for the given combination will be determined, referred to as M_5, as outlined below:

	$M_4\{P_4\} = 0.08$	$M_2\{\Theta\} = 0.92$
$M_3\{P_3\} = 0.2104$	0.0168	0.1936
$M_3\{\Theta\} = 0.7896$	0.0632	0.7264

$M_5\{P_5\} = \frac{0.0168+0.1936+0.0632}{1-0} = 0.2736$

$M_5\{\Theta\} = \frac{0.7264}{1-0} = 0.7264$

S12 (Yes = 0.12)

Then : $M_6\{P_6\} = 0.12$

$M_6\{\Theta\} = 1 - 0.12 = 0.88$

Following this, the fresh density metric for the given combination will be determined, referred to as M_7, as outlined below:

	$M_6\{P_6\} = 0.12$	$M_6\{\Theta\} = 0.88$
$M_5\{P_5\} = 0.2735$	0.0328	0.2407
$M_5\{\Theta\} = 0.7264$	0.0872	0.6392

$M_7\{P_7\} = \frac{0.0328+0.2407+0.0871}{1-0} = 0.3607$

$M_5\{\Theta\} = \frac{0.6393}{1-0} = 0.6393$

From the calculation above, the value of the risk density of AM disease or Metabolic Acidosis is as high as 0.3607

Execution of RULE 4 for diseases HE

RULE 4 = IF S04 AND S08 AND S10 AND S11 AND S22 AND S24 AND S25 AND S26 THEN HE

S04 (Yes = 0.07)

Then : $M_1\{P_1\} = 0.07$

$M_1\{\Theta\} = 1 - 0.07 = 0.93$

S08 (Yes = 0.06)

Then : $M_2\{P_2\} = 0.06$

$M_2\{\Theta\} = 1 - 0.06 = 0.94$

Following this, the fresh density metric for the given combination will be determined, referred to as M_3, as outlined below:

	$M_2\{P_2\} = 0.06$	$M_2\{\Theta\} = 0.94$
$M_1\{P_1\} = 0.07$	0.0042	0.0658
$M_1\{\Theta\} = 0.93$	0.0525	0.8742

$M_3\{P_3\} = \frac{0.0042+0.0658+0.0558}{1-0} = 0.1258$

$M_3\{\Theta\} = \frac{0.8742}{1-0} = 0.8742$

S10 (Yes = 0.06)

Then : $M_4\{P_4\} = 0.06$

$M_4\{\Theta\} = 1 - 0.06 = 0.94$

Following this, the fresh density metric for the given combination will be determined, referred to as M13, as outlined below:

	$M_4\{P_4\} = 0.06$	$M_2\{\Theta\} = 0.94$
$M_3\{P_3\} = 0.1258$	0.0075	0.1183
$M_3\{\Theta\} = 0.8742$	0.0631	0.8217

$M_5\{P_5\} = \frac{0.0075+0.1183+0.0631}{1-0} = 0.1889$

$M_5\{\Theta\} = \frac{0.8217}{1-0} = 0.8217$

S11 (Yes = 0.08)

Then : $M_6\{P_6\} = 0.08$

$M_6\{\Theta\} = 1 - 0.08 = 0.92$

Following this, the fresh density metric for the given combination will be determined, referred to as M_5, as outlined below:

	$M_6\{P_6\} = 0.08$	$M_6\{\Theta\} = 0.92$
$M_5\{P_5\} = 0.1889$	0.0151	0.1738
$M_5\{\Theta\} = 0.8217$	0.0657	0.7560

$M_7\{P_7\} = \frac{0.0151+0.1738+0.0657}{1-0} = 0.2547$

$M_5\{\Theta\} = \frac{0.7560}{1-0} = 0.7560$

From the calculation above, the density value of risk of HE disease or hemolysis is as high as 0.2547

Execution of RULE 5 for disease DV

RULE 5 = IF S02 AND S07 AND S08 AND S11 AND S27 AND S28 AND S29 AND S30 AND S31 THEN DV

S02 (Yes = 0.08)

Then : $M_1\{P_1\} = 0.08$

$M_1\{\Theta\} = 1 - 0.08 = 0.92$

S08 (Yes = 0.06)

Then : $M_2\{P_2\} = 0.06$

$M_2\{\Theta\} = 1 - 0.06 = 0.94$

Following this, the fresh density metric for the given combination will be determined, referred to as M_3, as outlined below:

	$M_2\{P_2\} = 0.06$	$M_2\{\Theta\} = 0.94$
$M_1\{P_1\} = 0.08$	0.0048	0.0752
$M_1\{\Theta\} = 0.92$	0.0552	0.8648

$M_3\{P_3\} = \frac{0.0048+0.0752+0.0552}{1-0} = 0.135$

$M_3\{\Theta\} = \frac{0.8742}{1-0} = 0.8648$

S11 (Yes = 0.08)

Then : $M_4\{P_4\} = 0.08$

$M_4\{\Theta\} = 1 - 0.08 = 0.92$

Following this, the fresh density metric for the given combination will be determined, referred to as M_5, as outlined below:

	$M_4\{P_4\} = 0.06$	$M_2\{\Theta\} = 0.94$
$M_3\{P_3\} = 0.135$	0.0081	0.1269
$M_3\{\Theta\} = 0.8648$	0.0518	0.8129

$$M_5\{P_5\} = \frac{0.081+0.1269+0.0518}{1-0} = 0.1869$$

$$M_5\{\Theta\} = \frac{0.8129}{1-0} = 0.8129$$

From the calculation above, the density value of risk of DV disease or Deep Vein Thrombosis is as much as 0.1869

C. Assess the yield of each disease

After the dampster shafer process is carried out, a diagnostic value will be obtained for each disease as follows:

1. Acute Respiratory Distress Syndrome = 0.5555
2. Acute Encephalopathy = 0.12
3. Asidosis Metabolik = 0.3607
4. Hemolisis = 0.2547
5. Deep Vein Thrombosis = 0.1869

From the value of the results of each disease, the largest value will be taken, namely the disease Acute Respiratory Distress Syndrome with a value 0.5555.

D. System Implementation

System implementation is done to implement interface design into a system. The result of this implementation is an Expert System application that can assist in the diagnosis of diseases due to complications of systemic inflammatory response syndrome (SIRS). The pages contained in this application in Figure 3:

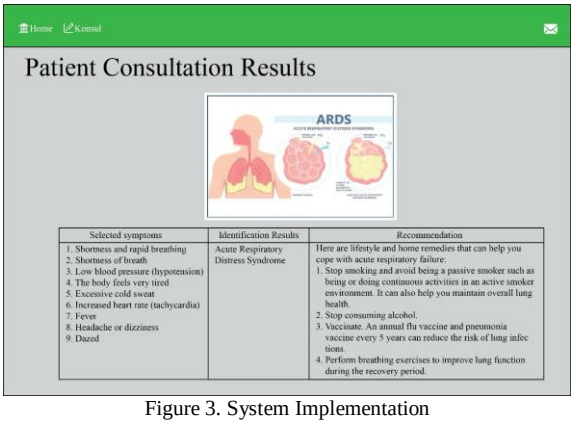


Figure 3. System Implementation

In Figure 3. Displayed the results of symptom identification consulted by the patient, with the same results as manual calculations, namely Acute Respiratory Distress disease with values 0.555.

E. Testing with Expert diagnostics

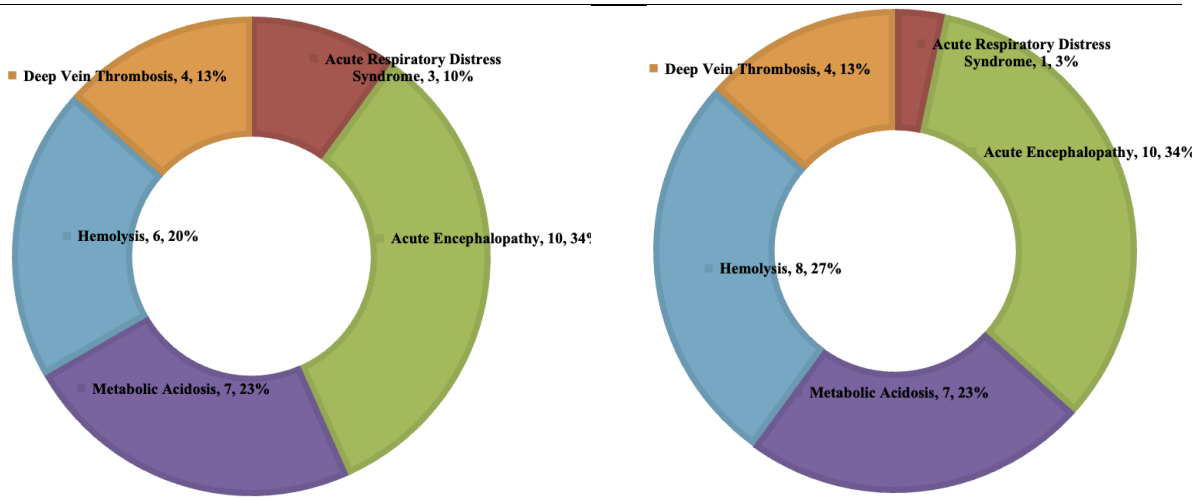
Furthermore, a trial will be carried out on 30 consultation data such as tables 5.

Table 5. Test Results

No	Kode	Diagnosa ES	Data Real	Hasil
1	PE_01	Acute Respiratory Distress Syndrome	Acute Respiratory Distress Syndrome	Valid
2	PE_02	Acute Encephalopathy	Acute Encephalopathy	Valid
3	PE_03	Deep Vein Thrombosis	Deep Vein Thrombosis	Valid
4	PE_04	Hemolisis	Hemolisis	Valid
5	PE_05	Deep Vein Thrombosis	Deep Vein Thrombosis	Valid
6	PE_06	Acute Encephalopathy	Acute Encephalopathy	Valid
7	PE_07	Deep Vein Thrombosis	Deep Vein Thrombosis	Valid
8	PE_08	Hemolisis	Hemolisis	Valid
9	PE_09	Hemolisis	Hemolisis	Valid
10	PE_10	Acute Respiratory Distress Syndrome	Hemolisis	Invalid
11	PE_11	Hemolisis	Hemolisis	Valid
12	PE_12	Hemolisis	Hemolisis	Valid
13	PE_13	Hemolisis	Hemolisis	Valid
14	PE_14	Acute Respiratory Distress Syndrome	Hemolisis	Invalid
15	PE_15	Acute Encephalopathy	Acute Encephalopathy	Valid
16	PE_16	Deep Vein Thrombosis	Deep Vein Thrombosis	Valid
17	PE_17	Asidosis Metabolik	Asidosis Metabolik	Valid
18	PE_18	Acute Encephalopathy	Acute Encephalopathy	Valid
19	PE_19	Deep Vein Thrombosis	Deep Vein Thrombosis	Valid
20	PE_20	Acute Encephalopathy	Acute Encephalopathy	Valid
21	PE_21	Acute Encephalopathy	Acute Encephalopathy	Valid
22	PE_22	Acute Encephalopathy	Acute Encephalopathy	Valid
23	PE_23	Asidosis Metabolik	Asidosis Metabolik	Valid
24	PE_24	Deep Vein Thrombosis	Deep Vein Thrombosis	Valid
25	PE_25	Acute Encephalopathy	Acute Encephalopathy	Valid
26	PE_26	Deep Vein Thrombosis	Deep Vein Thrombosis	Valid
27	PE_27	Acute Encephalopathy	Acute Encephalopathy	Valid
28	PE_28	Asidosis Metabolik	Asidosis Metabolik	Valid
29	PE_29	Asidosis Metabolik	Asidosis Metabolik	Valid
30	PE_30	Acute Encephalopathy	Acute Encephalopathy	Valid

From both Figure 4, it can be seen that the difference in identification results in expert systems and real data is found in data 10 and data 14. So the accuracy level of this expert system is 0.93 or 93%.

DOI: https://doi.org/10.52436/1.jutif.2024.5.3.2021
p-ISSN: 2723-3863
e-ISSN: 2723-3871



(a) (b)

Figure 4. (a)Expert System Identification Results, (b) Real Data Identification Results

For more clarity on the number of differences in patient identification results in each disease can be seen in Figures 4.

4. DISCUSSION

This study demonstrates the use of the Dempster-Shafer method in diagnosing Inflammatory Response Syndrome by utilizing a detailed dataset of clinical symptoms including shortness of breath and rapidity, shortness of breath, hypotension, excessive fatigue, cold sweat, tachycardia, fever, headache or dizziness, and confusion Although the system achieved an impressive accuracy rate of 93%, there were significant differences in results in two of the samples tested. i.e. the 10th data and the 14th data. This difference shows that although Dempster-Shafer is effective in many cases, there is still room for improvement, especially in the handling of atypical or rare cases.

Compared to previous expert system studies using the Certainty Factor method, such as those conducted by Agussalim et al. (2022) which only achieved 80% accuracy in disease diagnosis [23], this study shows increased accuracy. But it also emphasizes the importance of integrating feedback from clinical experts to refine the knowledge base, an aspect that is in line with the findings in this study about expanding knowledge from other experts. Furthermore, the application of additional machine learning technologies such as Random Forest and SVM allows providing more consistent results in complex diagnostic cases.

To address the differences in identified outcomes, the study recommends incorporating an interdisciplinary approach in training the Dempster-Shafer system. The addition of insights from a variety of specialists, not only from the medical field but also from data science, can improve the system's ability to interpret variations in complex and diverse symptoms. This approach is expected to not only improve the accuracy but also adaptability of the system in dealing with more diverse cases, following trends in recent research that integrate various methodologies to improve diagnostic efficiency and effectiveness.

5. CONCLUSION

This research succeeded in developing an expert system that utilizes the Dempster-Shafer method to carry out early identification of complications SIRS, By integrating the main clinical symptoms such as shortness of breath and rapidity, shortness of breath, hypotension, excessive fatigue, cold sweat, tachycardia, fever, headache or dizziness, and confusion. From the evaluation performed, this system can calculate the probability of complications with a significant value, where Acute Respiratory Distress Syndrome (ARDS) shows the highest probability of 0.5555, followed by Metabolic Acidosis at 0.3607, Hemolysis at 0.2547, Deep Vein Thrombosis (DVT) at 0.1869, and Acute Encephalopathy at 0.1869, and Acute Encephalopathy at 0.12.

In applying it to real data, the expert system demonstrated impressive performance with an accuracy rate of up to 93%, despite differences in the two identification results, namely data 10 and data 14. These differences provide valuable insights and indicate room for system improvement through knowledge base enrichment, particularly by adding insights from other medical experts to improve the predictive capabilities of the system.

Based on the results of the study, the expert system developed offers a reliable method for diagnostic assistance of SIRS complications in clinical environments. The success of this system confirms the potential integration of information technology and artificial intelligence in improving the quality of patient care. Furthermore, the continued development of the system is expected to not only strengthen diagnostic accuracy but also provide more

precise therapeutic recommendations for patients with various complications of SIRS.

REFERENCES

[1] S. Chakraborty, H. Kaynak, dan J. A. Pagán, "Bridging hospital quality leadership to patient care quality," *Int. J. Prod. Econ.*, vol. 233, hlm. 108010, Mar 2021, doi: 10.1016/j.ijpe.2020.108010.

[2] S. Mamoor, "Global transcriptional profiling of CD15+ granulocytes from patients with septic shock and systemic inflammatory response syndrome (SIRS)." 2 Oktober 2019. doi: 10.31219/osf.io/tuqnd.

[3] K. Grozdanovski *dkk.*, "Association of Systemic Inflammatory Response Syndrome with Bacteremia in Patients with Sepsis," *PRILOZI*, vol. 40, no. 2, hlm. 51–56, Okt 2019, doi: 10.2478/prilozi-2019-0014.

[4] N. V. Zotova, Y. A. Zhuravleva, T. E. Zubova, dan E. Y. Gusev, "Integral estimation of systemic inflammatory response under sepsis," *Gen. Physiol. Biophys.*, vol. 39, no. 01, hlm. 13–26, 2020, doi: 10.4149/gpb_2019043.

[5] N. Cui *dkk.*, "Deep vein thrombosis in acute respiratory distress syndrome caused by bacterial pneumonia," *BMC Pulm. Med.*, vol. 21, no. 1, hlm. 264, Agu 2021, doi: 10.1186/s12890-021-01632-1.

[6] Q. Gong, Y. Xue, X. Li, L. Song, dan L. Zhu, "DL-3-n-butylphthalide attenuates lipopolysaccharide-induced acute lung injury via SIRT1-dependent and -independent regulation of Nrf2," *Int. Immunopharmacol.*, vol. 74, hlm. 105658, Sep 2019, doi: 10.1016/j.intimp.2019.05.043.

[7] Dr. M. Mattous, Dr. N. Jbili, dan Dr. J. Laoutid, "The Risk of Acute Respiratory Distress Syndrome in Patients with Subarachnoid Hemorrhage, About A Case," *Sch. J. Med. Case Rep.*, vol. 08, no. 02, hlm. 245–247, Feb 2020, doi: 10.36347/sjmcr.2020.v08i02.040.

[8] V. V. Liubchenko, N. O. Komleva, S. L. Zinovatna, dan J. Briggs, "Methodology for illness detection by data analysis techniques," *Appl. Asp. Inf. Technol.*, vol. 6, no. 3, hlm. 273–285, Sep 2023, doi: 10.15276/aait.06.2023.19.

[9] D. S. Br Ginting, "Web-Based Expert System for Diagnosis Mycetoma Using Dempster-Shafer Methods," *Instal J. Komput.*, vol. 15, no. 01, hlm. 1–8, Jun 2023, doi: 10.54209/jurnalkomputer.v15i01.52.

[10] G. Gunadi dan A. Nursami, "EXPERT SYSTEM FOR DIAGNOSIS OF KIDNEY DISEASE WITH DEMPSTER SHAFER METHOD AT MEDIKA PLAZA CLINIC," *J. DISPROTEK*, vol. 14, no. 2, hlm. 166–176, Jul 2023, doi: 10.34001/jdpt.v14i2.4028.

[11] J. Manurung, Y. Perwira, dan B. Sinaga, "Expert System to Diagnose Dental and Oral Disease Using Naive Bayes Method," dalam *2022 IEEE International Conference of Computer Science and Information Technology (ICOSNIKOM)*, Laguboti, North Sumatra, Indonesia: IEEE, Okt 2022, hlm. 01–04. doi: 10.1109/ICOSNIKOM56551.2022.10034871.

[12] A. Ellouze, O. Kahouli, M. Ksantini, H. Alsaif, A. Aloui, dan B. Kahouli, "Artificial Intelligence-Based Diabetes Diagnosis with Belief Functions Theory," *Symmetry*, vol. 14, no. 10, hlm. 2197, Okt 2022, doi: 10.3390/sym14102197.

[13] I. Istiadi, E. B. Sulistiarini, R. Joegijantoro, dan D. U. Effendy, "Infectious Disease Expert System Using Dempster Shafers With Recommendations for Health Services," *J. RESTI Rekayasa Sist. Dan Teknol. Inf.*, vol. 4, no. 1, hlm. 17–27, Feb 2020, doi: 10.29207/resti.v4i1.1332.

[14] A. Iskandar, "Sistem Pakar Dalam Mendiagnosa Penyakit Parkinson Menerapkan Metode Dempster-Shafer," *J. Inf. Syst. Res. JOSH*, vol. 4, no. 3, hlm. 847–854, Apr 2023, doi: 10.47065/josh.v4i3.3320.

[15] Y. B. Arya, "Flash Damage Expert System Using the Dempster Shafer Method," *Int. J. Mech. Comput. Manuf. Res.*, vol. 12, no. 1, hlm. 10–15, Mei 2023, doi: 10.35335/computational.v12i1.92.

[16] S. Suryadin, Nur Fitrianingsih, dan Ita Fitriati, "Design Of An Expert System To Diagnose Diseases In Onion Plants Using The Web-Based Dempster Shafer Method," *Eng. J. Mechatron. Educ.*, vol. 1, no. 1, hlm. 28–35, Jan 2024, doi: 10.59923/mechatronics.v1i1.47.

[17] N. Elmi, Rolly, dan A. Dermawan, "APPLICATION OF EXPERT SYSTEM USING FORWARD CHAINING METHOD FOR WEB-BASED DIAGNOSIS OF CHILD DIARRHEA," *J. Tek. Inform. Jutif*, vol. 3, no. 3, hlm. 553–562, Jun 2022, doi: 10.20884/1.jutif.2022.3.3.244.

[18] A. Ghasemi dan M. Naeimaeyi Aali, "Clinical Reasoning and Artificial Intelligence," *Ann. Mil. Health Sci. Res.*, vol. 21, no. 1, Agu 2023, doi: 10.5812/amh-134440.

[19] L. J. Muhammad, E. J. Garba, N. D. Oye, G.

M. Wajiga, dan A. B. Garko, "Fuzzy rule-driven data mining framework for knowledge acquisition for expert system," dalam *Translational Bioinformatics in Healthcare and Medicine*, Elsevier, 2021, hlm. 201–214. doi: 10.1016/B978-0-323-89824-9.00017-3.

[20] "EXPERT SYSTEM TO DIFFERENT MIXED DISEASE IN BABY USING CBR (CASE BASE REASONING) METHOD," *J. Crit. Rev.*, vol. 7, no. 05, Mar 2020, doi: 10.31838/jcr.07.05.08.

[21] M. Rumsamrong, A. Chiou, dan L. Li, "Self-Explanatory Capabilities in Intelligent Decision Support Systems in Resource Management," dalam *Complex, Intelligent, and Software Intensive Systems*, vol. 993, L. Barolli, F. K. Hussain, dan M. Ikeda, Ed., dalam Advances in Intelligent Systems and Computing, vol. 993. , Cham: Springer International Publishing, 2020, hlm. 356–367. doi: 10.1007/978-3-030-22354-0_32.

[22] D. Aldo, "Sistem Pakar Diagnosis Hama Dan Penyakit Bawang Merah Menggunakan Metode Dempster Shafer," *Komputika J. Sist. Komput.*, vol. 9, no. 2, hlm. 85–93, Okt 2020, doi: 10.34010/komputika.v9i2.2884.

[23] Agussalim, N. Astuti Triana, E. Maya Safitri, A. Wulansari, dan S. Fitri Ana Wati, "Accuracy of Kidney Disease Expert System Based On Certainty Factor and Dempster Shafer Algorithm," *IJCONSIST J.*, vol. 3, no. 2, hlm. 19–24, Jun 2022, doi: 10.33005/ijconsist.v3i2.66.