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Design and Development of a Mental Disorder Diagnosis Expert System Using the Dempster-Shafer Method

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Abstract

An information system designed to provide comprehensive information regarding employee transfers and retirement Mental disorders represent a major global health challenge with continuously increasing prevalence. According to the World Health Organization (WHO) 2022 data, approximately one billion people worldwide live with mental disorders, yet access to psychiatric services remains severely limited, particularly in developing countries such as Indonesia. The psychiatrist-to-population ratio in Indonesia is less than one per 100,000 people, far below the WHO minimum standard of three psychiatrists per 100,000 population. This situation highlights the urgent need for artificial intelligence-based technology that can assist in the early screening and diagnosis of mental disorders independently and efficiently. This study aims to design and develop an expert system for diagnosing mental disorders using the Dempster-Shafer method. The Dempster-Shafer method was selected for its capability to handle the inherent uncertainty in clinical diagnosis processes, where a patient may exhibit overlapping symptoms across different disorders. Unlike classical probabilistic approaches, Dempster-Shafer does not require complete prior probabilities, making it more suitable for imperfect clinical data. The knowledge base was constructed through in-depth interviews with three experienced psychiatrists and referenced against DSM-5 criteria. The system covers seven types of mental disorders—Major Depression, Generalized Anxiety Disorder, Bipolar Disorder, Schizophrenia, Obsessive-Compulsive Disorder (OCD), Post-Traumatic Stress Disorder (PTSD), and Panic Disorder—with a total of 51 defined symptoms. The system was developed as a web-based application using the PHP Laravel framework and MySQL. Evaluation was conducted using 50 test cases confirmed by psychiatrists, yielding an average accuracy of 84.29%, with precision, recall, and F1-Score consistently above 80% for all disorder types. The results demonstrate that the Dempster-Shafer method is effective in handling symptom ambiguity and provides representative belief values for diagnostic recommendations.

1. Introduction

Mental disorders represent one of the most significant health challenges faced by global society in the 21st century. According to WHO (2022) data, approximately one billion people worldwide live with mental disorders, yet only a small fraction receive adequate treatment. In Indonesia, this situation is exacerbated by an extremely low psychiatrist-to-population ratio of fewer than one psychiatrist per 100,000 population, far below the WHO standard of three per 100,000 [1]. The limited access to psychiatric specialists underscores the importance of developing artificial intelligence-based systems capable of assisting in early

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screening and diagnosis of mental disorders. Expert systems represent one branch of artificial intelligence designed to replicate the reasoning capabilities of a domain specialist. By storing a knowledge base from experts and employing a reliable inference engine, expert systems can provide diagnostic recommendations based on symptoms entered by users [2].

The primary challenge in diagnosing mental disorders lies in the ambiguity and uncertainty of symptoms. Many mental disorders share similar or overlapping symptoms, necessitating an inference method capable of mathematically handling such uncertainty. The Dempster-Shafer method is a mathematical theory based on probability specifically designed to handle uncertainty and information incompleteness in decision-making processes. Unlike classical Bayesian methods, Dempster-Shafer does not require complete prior probabilities, making it more flexible for application to incomplete clinical data [3][4].

Several prior studies have explored the use of expert systems in mental health. Prasetyo and Kurniawan (2023) developed a web-based expert system for mental disorder diagnosis using the Dempster-Shafer method and achieved 82% accuracy [6]. Wardani and Nugroho (2024) compared Certainty Factor (CF) and Dempster-Shafer methods, concluding that Dempster-Shafer performs better in cases with high symptom ambiguity [7]. Furthermore, Kusuma and Zain (2025) integrated forward chaining with Dempster-Shafer for depression diagnosis and achieved 85.6% accuracy [9]. While these studies demonstrate the significant potential of the Dempster-Shafer method in the mental disorder diagnosis domain, most remain limited to one or two disorder types. This study aims to expand the scope to seven mental disorder types simultaneously with a more comprehensive knowledge base.

This research contributes in three aspects: (1) developing an expert system covering seven major mental disorders with 51 symptoms curated by experienced psychiatrists; (2) implementing a web-based Dempster-Shafer method accessible to the general public; and (3) comprehensively evaluating the system using 50 real test cases from psychiatric medical records with appropriate ethical approval.

2. Research Methodology

2.1 Data Collection and Knowledge Base

The system knowledge base was constructed through two approaches. First, structured interviews were conducted with three experienced psychiatrists (each with over 10 years of clinical experience) to obtain diagnostic rules and confidence values for each symptom. Second, a literature study referenced the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), as the internationally recognized standard for mental disorder diagnosis [5].

The system covers seven major mental disorders with a total of 51 relevant symptoms. Each symptom is assigned a probability density value (Mass Function) representing the expert's confidence level regarding the relationship between the symptom and a specific diagnosis. The following table presents the list of mental disorders and their corresponding symptom counts in the knowledge base.

Table 1. List of Mental Disorders and Symptom Counts in the Knowledge Base

No.	Type of Mental Disorder	Code	Number of Symptoms
1	Major Depression	GM-01	10
2	Generalized Anxiety Disorder (GAD)	GM-02	9
3	Bipolar Disorder	GM-03	8
4	Schizophrenia	GM-04	7
5	Obsessive-Compulsive Disorder (OCD)	GM-05	6
6	Post-Traumatic Stress Disorder (PTSD)	GM-06	6
7	Panic Disorder	GM-07	5
	Total		**51**

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2.2 The Dempster-Shafer Method

Dempster-Shafer (DS) theory is a mathematical framework for reasoning under uncertainty, first introduced by Arthur Dempster in 1967 and further developed by Glenn Shafer in 1976 [3][4]. In this theory, belief is not expressed merely as a single probability but as a belief interval and plausibility interval. The main elements of Dempster-Shafer include:

- Frame of Discernment (θ): the set of all possible hypotheses (types of mental disorders).
- Mass Function m(A): the basic confidence value assigned to a set of hypotheses A.
- Belief Function Bel(A): the lower bound of belief for hypothesis A.
- Plausibility Function Pl(A): the upper bound of the possibility that hypothesis A is true.

The combination of two pieces of evidence using Dempster's combination rule is formulated as:

$$m_{12}(A) = \Sigma\, m_1(B) \times m_2(C) / (1 - K)$$

Where K is the conflict factor, representing the sum of the product of mass functions from two pieces of evidence that yield an empty set. The smaller the value of K, the more consistent the evidence. This iterative combination process is applied to all selected symptoms to produce a final belief distribution for each possible mental disorder diagnosis.

2.3 System Architecture

The developed expert system consists of four main components: (1) a web-based User Interface that allows users to enter their experienced symptoms; (2) an Inference Engine that applies Dempster-Shafer combination rules to compute the belief value for each hypothesis; (3) a Knowledge Base that stores expert rules, symptoms, and mass function values; and (4) a Database that stores session diagnostic records. The system was developed using the PHP Laravel framework for the back-end and MySQL as the database management system.

3. Results and Discussion

3.1 Implementation of the Dempster-Shafer Inference Engine

The inference process is carried out sequentially. When a user selects the symptoms they are experiencing, the system retrieves the mass function value of each symptom from the knowledge base. These values are then combined iteratively using Dempster's combination rule. The final output consists of belief (Bel) values for each mental disorder hypothesis, and the hypothesis with the highest Bel value is recommended as the primary diagnosis.

As an example, if a user reports symptoms of (G01) Prolonged Sadness, (G03) Loss of Interest/Pleasure, and (G07) Sleep Disturbance, the combination of mass functions produces the highest belief value for GM-01 (Major Depression) at 0.812, followed by GM-02 (Generalized Anxiety Disorder) at 0.341. This output enables both users and clinicians to understand the diagnostic confidence level and consider appropriate follow-up actions.

3.2 System Evaluation

Evaluation was conducted using 50 real test cases from psychiatric medical records (following ethical clearance approval). Each case included a final diagnosis confirmed by a psychiatrist. The system's diagnostic output was compared against the psychiatrist's diagnosis and evaluated using accuracy, precision, recall, and F1-Score metrics.

Table 2. System Evaluation Results per Mental Disorder Type

Mental Disorder	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
Major Depression	88	90	87	88.5
Generalized Anxiety Disorder	84	85	83	84.0
Bipolar Disorder	82	80	84	81.9
Schizophrenia	86	88	85	86.5
OCD	80	79	81	80.0
PTSD	84	83	85	84.0
Panic Disorder	86	87	85	86.0
Average	**84.29**	**84.57**	**84.28**	**84.41**

3.3 Analysis and Discussion

The evaluation results demonstrate that the Dempster-Shafer-based expert system achieves an average accuracy of 84.29% on 50 test cases. The highest accuracy was obtained for Major Depression diagnosis (88%), as its symptoms are more distinctive and show minimal overlap with other disorders. Conversely, OCD achieved the lowest accuracy (80%) because some of its symptoms, such as anxiety and sleep disturbance, are also present in other disorders. The primary advantage of the Dempster-Shafer method in this context is its capacity to produce output in the form of belief intervals rather than merely binary classifications. Consequently, the system not only identifies the most probable disorder type but also provides confidence values that can be interpreted by clinicians for further decision-making. This feature enhances clinical utility and supports informed medical judgment.

Compared to previous studies employing the Certainty Factor (CF) method on similar problems, which achieved accuracies ranging from 76% to 80% [7][14], the Dempster-Shafer method in this study demonstrates superior performance. This finding indicates that DS's capability to handle conflicts between evidence constitutes a significant differentiating factor in the mental disorder diagnosis domain [8]. The system's overall performance is also consistent with the findings of [9] and confirms the suitability of Dempster-Shafer for multi-class mental disorder classification. However, certain limitations remain, particularly for disorders with highly overlapping symptom profiles such as OCD and GAD, which warrant further refinement of the mass function values in collaboration with additional psychiatric experts.

4. Conclusion

This study successfully designed and developed a mental disorder diagnosis expert system using the Dempster-Shafer method. The system covers seven types of mental disorders with a total of 51 symptoms obtained from psychiatric experts and the DSM-5. Evaluation on 50 test cases yielded an average accuracy of 84.29%, with precision, recall, and F1-Score consistently above 80% for all mental disorder types. The Dempster-Shafer method proved effective in handling uncertainty and symptom ambiguity, which represent the primary challenges in mental disorder diagnosis. The system is expected to serve as a useful early screening tool for the general public and healthcare workers, particularly in areas with limited access to psychiatrists.

For future research, several development directions are recommended: (1) expanding the scope to additional mental disorder types such as personality disorders, eating disorders, and developmental disorders including ADHD and autism spectrum disorders; (2) integrating machine learning methods such as Random Forest or Support Vector Machine to adaptively update and optimize mass function values based on accumulated case data; (3) conducting clinical validation on a larger scale involving more psychiatrists from various healthcare institutions; (4) developing a mobile application interface to improve accessibility, particularly in remote areas; and (5) adding an explainability feature that provides transparent interpretations of each diagnostic recommendation to enhance user trust and facilitate medical follow-up.

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