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Certainty Factor vs. Dempster-Shafer: Evaluating Accuracy in an Android Expert System for Tilapia Disease Diagnosis

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Abstract

This study aims to develop an Android-based expert system to help fish farmers detect diseases in tilapia (Oreochromis niloticus) quickly and accurately. This system implements two inference methods, namely Certainty Factor (CF) and Dempster-Shafer (DS), which are then compared to assess their effectiveness and accuracy in the diagnosis process. The research was conducted in Purwonegoro Subdistrict, Banjarnegara Regency, which is one of the centers of tilapia farming in Central Java.The knowledge base in this system is compiled based on disease symptom data obtained from interviews with experts and scientific literature references. The developed Android application allows users to enter symptoms that appear on fish to get diagnosis results along with confidence levels and treatment suggestions. System testing is carried out using real case data from the field, and the diagnosis results are compared with evaluations by experts.The results show that both methods are able to provide fairly accurate diagnoses. The Certainty Factor method excels in terms of speed and simplicity in calculation, while the Dempster-Shafer method is better able to handle uncertainty from non-specific symptom combinations. The accuracy of the Dempster-Shafer method is slightly higher than the Certainty Factor, but the difference is not statistically significant.This expert system is expected to be a practical solution for fish farmers in identifying diseases early on, thus supporting the increase in productivity and efficiency of tilapia farming in the research area.

Keyword: Expert System, Tilapia, Certainty Factor, Dempster-Shafer, Fish Disease.

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INTRODUCTION

Aquaculture in Indonesia is one of the main sectors in economic growth. Indonesia is the second largest tilapia producer in the world with a contribution of about 25.89% to world tilapia production. In Indonesia, tilapia is the largest production among other aquaculture species. Tilapia production growth annually reached 11.61% from 2011 to 2018 (Gustiano et al., 2023). West Java Province is the largest tilapia producer, followed by West Sumatra, South Sumatra, and Central Java (Gustiano et al., 2023).

Table 1 Stillwater pond enlargement production (kg) in 2024
Source: Department of Agriculture, Fisheries and Food Security of Banjarnegara Regency

Bawal	2,230,482
Gurame	2,968,208
Catfish	17,685,093
Goldfish	546,460
Mujair	596,361
Nila	14,545,068
Nilem	840,929
Patin	428,874
Tambakan	178,830

In table 1 this study presents data on the production of enlarged stillwater ponds in 2024 in Banjarnegara Regency. Banjarnegara Regency is the largest freshwater fish farmer in Central Java Province.

Table 2. Data on fisheries business actors as of March 2024

Number of Valid Cultivators	:	25,815 RTP
Total potential land area	:	16,708,014 m^2(1,671 Ha)
Total Productive Land Area	:	4,592,507 m^2(459 Ha)
Number of fish farmers by business type		
Freshwater Ornamental Fish	:	358 RTP
Land area	:	265,286 m^2(27 Ha)
Freshwater hatcheries and nurseries	:	1,746 RTP

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Land area	:	658,353 $m^{(2)}$ (65.8 Ha)
Fresh driftnet enlargement	:	50 RTP
Land area	:	15,204 $m^{(2)}$ (1.5 Ha)
Cage Enlargement	:	11 RTP (update to Freshwater Floating Nets)
Land area	:	3662 m^2
Quiet water pond enlargement	:	23,501 RTP
Land area	:	3,370,561 m^2(337 Ha)
Mina padi	:	23 RTP
Land area	:	149,350 $m^{(2)}$ (15 Ha)
Simple pond enlargement	:	40 RTP (upgrade to still water pool)
Land area	:	99.168 m^2
Rapid water pond enlargement	:	22 RTP (upgrade to still water pool)
Land area		5.548 m^2

Table 2 illustrates data on Fishery Households (RTP) in Banjarnegara Regency. Based on interviews with extension workers on January 25, 2025, for the inland fisheries sector, Banjarnegara Regency has several potential fish farms, among others: Pond Aquaculture with an area of around 793.3 hectares with a total production of 40,509 tons in 2024. Floating Net Aquaculture with an area of 5.9 hectares with a total production of 384 tons in 2024. Minapadi Fishery Cultivation with an area of 10.9 Ha. production of 21.5 tons in 2024.

With the development of the industry, land for freshwater fish farming is getting smaller. But on the other hand, market demand is increasing. One of the freshwater fish farms is Tilapia. Tilapia is a type of freshwater fish that is easily developed in tropical and temperate climates (Saputra et al., 2022). However, the obstacle is fish disease caused by viruses. Recently, in some areas there have been cases of mass mortality in tilapia fish farming, which may be infected with TiLV disease. This virus is a genus of the Orthomyxoviridae family, which replicates in the cell nucleus in fish tissue (Saragih & Junaidi, 2021). There are many factors that cause the virus to develop in water, such as temperature, water acidity, water pH.

Since 2014, the Ministry of Marine Affairs and Fisheries (KKP) has classified this disease as a major disease in tilapia in Indonesia. Based on the characteristics of Streptococcus agalactiae isolates isolated from diseased tilapia from various regions in Indonesia, two biotypes were found consisting of β-hemolytic S. agalactiae (biotype I) and non-hemolytic S. agalactiae (biotype II). Biotype I causes disease with acute patterned mortality; while biotype II causes disease with chronic and persistent patterned mortality. Based on susceptibility to S. agalactiae

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during artificial infection testing, it is known that all tilapia strains that have been released to the public for aquaculture purposes have susceptibility to infection with the bacteria; although each strain has a different level of susceptibility(Taukhid et al., 2023) .

There are many farmers experiencing fish harvest failure due to ignorance of knowledge about Tilapia fish farming. Faced with this situation, the government through the Aquaculture Technology Development Agency (BPTPB) conducts routine counseling. But the problem is that extension workers are limited. Meanwhile, the area of Tilapia cultivation is very large. Based on interviews with extension workers in the field, the Agency for the Development of Aquaculture Technology (BPTPB) needs an information system that can help farmers to find out knowledge about Tilapia fish farming.

Based on visits and interviews with the Agriculture, Fisheries and Food Security Office of Banjarnegara District, there are 5 extension officers. The number of farmer groups in the database of the Banjarnegara District Agriculture, Fisheries and Food Security Office is more than 800, both active and inactive. Meanwhile, the number of freshwater fish and ornamental fish farmers is more than 29,000.

Given the data on farmer groups and cultivators in Banjarnegara Regency, this is disproportionate to the number of extension workers available. Based on this data, the researcher proposed an expert system for fish disease detection. There are two approaches taken to validate the decision of the expert system. Researchers chose the Certainty Factor and Dempster-Shafer methods. Both methods will be compared to get the most accurate validation results from this system.

LITERATURE REVIEW

Dempster Shafer Method

The research system uses the Dempster Shafer method. As an uncertainty reasoning tool, the Dempster-Shafer evidence theory was first presented by Dempster in 1967 [upper]. Soon after, it was developed by Shafer (Shafer, 2016) in 1976. DST (Dempster-Shafer Theory) is an extension of general Bayesian statistical inference where evidence can be associated with multiple events. In other words, in DST probabilities can be assigned to a single event or each event. This versatility to represent and combine different types of evidence obtained from different sources is one of the two main advantages of DST (Rathman et al., 2018).

Thanks to its flexibility and effectiveness in modeling uncertainty without prior information, the Dempster-Shafer evidence theory has been widely used in various application fields, such as decision making, risk analysis pattern recognition, supplier selection, fault

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diagnosis, and so on (Xiao, 2018).

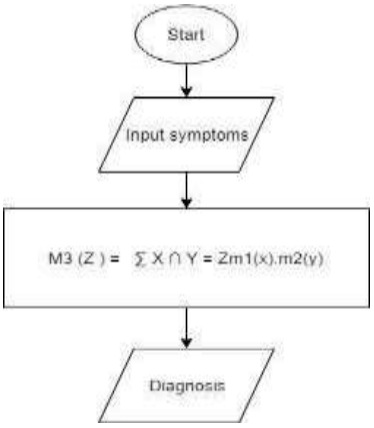


Figure 1. System flow with the Dempster Shafer method

Due to its flexibility and effectiveness in modeling uncertainty without prior information, Dempster-Shafer evidence theory has been widely used in various application fields, such as decision making, risk analysis pattern recognition, supplier selection, fault diagnosis, and so on . Figure 2.1 illustrates a formula that appears to be part of the Dempster-Shafer Theory (DST) method in evidence theory or theory of belief functions .

Table 3. Dempster Shafer Scale

No.	Symptom Code	Scale
1	Very weak	0.2
2	Weak	0.4
3	Fair	0.6
4	Strong	0.8
5	Very strong	1

Table 3 illustrates the weights of the mass function denoted by m. These weights are assigned to symptoms to determine the confidence of a particular disease.

Certainty Factor Method

As a comparison to Dempster Shafer's theory, researchers compared it with the Certainty Factor Method. Certainty Factor is a value that reflects the level of confidence in a hypothesis based on existing information. The factors of a disease's symptoms will be calculated using the

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CF method, so that accurate types of complaints can be obtained (Kirana et al., 2019).

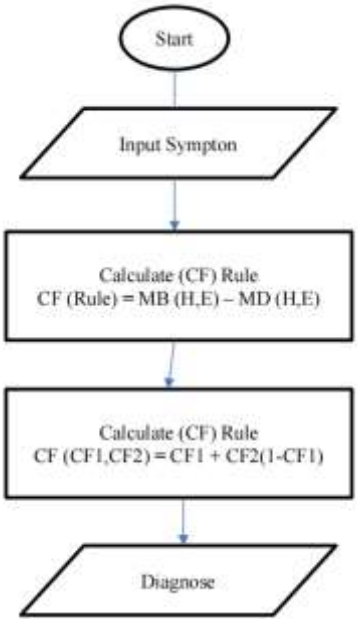


Figure 2. **Certainty Factor system flow**

Figure 2 illustrates the final value of the level of certainty towards a conclusion. The combined CF is the final CF of a proposed conclusion. This value is influenced by all parallel CFs of the rules that produce the conclusion. If different symptoms cause the same disease, then the calculation follows the general Certainty Factor equation.

For example, if symptom G (G1, G2, ..., Gn) produces disease P, and there is a value of E (E1, E2, ..., En) which also causes disease P, then there are values of CF1 (P, G) and CF2 (P, G). The level of certainty produced by the system in determining the diagnosis is the combined CF formulated in equation (Kirana et al., 2019)

$$\text{Combined CF}[CF1, CF2] = CF1 + CF2 \times (1 - CF1) \quad (1)$$

In the calculation with the CF model there is a scale for expert term interpretation. The knowledge obtained will be presented in the form of a rule to find a conclusion about a disease (Chandra et al., 2020).

Table 4. Certainty Factor Scale

No.	Symptom Code	Scale
1	Don't know	0
2	Maybe	0.4

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3	Most likely	0.6
4	Maybe	0.8
5	Definitely	1

Table 4 hows the scale that will be used to determine the rule to be diagnosed. Based on the two method charts, symptoms were found to be determined in the rules of each method. The symptoms found were 26 as in table 4.

Table 5. Symptoms of Fish Diseace

Code	Description
G1	Pale body / Around the wound covered with less bright pigment
G2	Decreased appetite / fish refuse food
G3	Thin / slow growth
G4	Restless / nervous / fish swim irregularly / like to jump
G5	Slow movement
G6	Itching / Rubbing the body on surrounding objects
G7	Rapid breathing / shortness of breath / Respiratory problems
G8	Skin irritation / inflammation / red color on the skin / red spots on the stomach / red spots on the base of the fins, anus and chest
G9	Excess mucus / excess mucus / mucus on the gills
G10	Damaged fins, shrunken, and falling out / broken fin tips
G11	Weak / lethargic / less active
G12	Dark body / Dark body color / Dark skin color / Dark color under the jaw
G13	Approaching the incoming water / Staying on the edge of the cage
G14	Pale or swollen gills
G15	Protruding eyes / Damaged and slightly protruding eyes / Blurred eyes / Cataracts
G16	Bleeding / bleeding on the gill cover / bleeding wounds on the body / bleeding on the tail fin around the anus / Hemorrhagic in the gill area
G17	Bloated stomach / Swelling of the abdominal cavity
G18	Ulcers / Wounds around the mouth, head, body / fins / Infection around the mouth like threads / Wounds on the fish's body
G19	Rough skin
G20	Loose scales
G21	Soft stomach

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G22	Suffocation
G23	There are white spots on the dorsal fin / White spots appear on the body, fins, skin / gills
G24	Reddish gills / Infected and reddish gills / Severe necrosis of the gills, red black and rotting
G25	There is a lump on the fish's body
G26	A white layer like cotton appears

Both methods will be developed in one system. Users will use all methods and will assess decisions that are in accordance with field experience. Both methods will be tested to determine the accuracy of the validity of decisions based on the weight of each option. In addition, researchers will test the extent to which this system affects farmers' needs based on experience using knowledge-based systems.

METHOD

Spiral Research Method

The Spiral Method for software development is used in this study. The research team uses the Spiral Method as a framework for software system development to guide the program. A practical strategy for extensive software and system development initiatives is the Spiral Method.

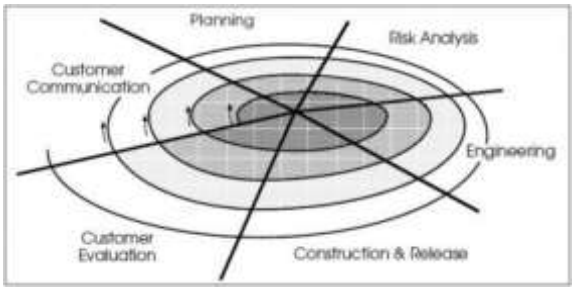


Figure 3. Spiral Method

Figure 3 illustrates the stages of the Spiral Method. The Spiral Method represents a realistic approach to large-scale system and software development. This model provides robust support for risk management (Doshi & Jain, 2021). The Spiral Method stages are as follows:

1. Planning: The research team (consisting of 3 lecturers and 3 students) develops a plan for the expert system prototype to be created. The team prepares the prototype

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components to be presented to partners for evaluation and further development (Anakotta & Adhy, n.d.).

2. Risk Analysis: The research team and partners collaboratively analyze potential risks in developing the expert system. Responsibilities are allocated according to capacity - for instance, partners provide laboratory facilities, computers, and internet access.
3. Engineering: The research team and students design and develop various learning materials for implementation in the expert system, including animations, videos, and audio elements. The existing system requires technological enhancements to improve performance. The expert system implements Application Programming Interface (API) technology, resulting in a more lightweight system.
4. Construction & Release: The research team and students conduct training sessions for partners on using the expert system.
5. Customer Evaluation: The research team and students document the partners' evaluation of the expert system usage.
6. Customer Communication: The research team and partners collaborate to promote the system to end-users within partner organizations, facilitating large-scale development of the expert system.

During the planning stage, researchers held interviews with two categories of experts: experienced tilapia fish farmers and Fisheries extension officers from relevant government agencies. These experts served as validators for the expert system's decision-making process based on the Certainty Factor (CF) and Dempster-Shafer (DS) Methods.

Experts from the Department provided knowledge to the researchers based on the handbook formulated by the Directorate of Aquatic Zones and Fish Health; Directorate General of Aquaculture; Ministry of Marine Affairs and Fisheries in 2018. Based on this guidebook, the research team classified the types of diseases according to the observed symptoms. Additionally, the research team consulted several journals that discussed diseases affecting Nile Tilapia.

Experts from the fish farmer groups shared their knowledge with the researchers regarding symptoms based on years of personal experience. This served as a complement to the knowledge that would be integrated with academic and scientific understanding.

At the customer communication stage, the researchers, together with experts, conducted outreach regarding the expert system. This stage aims to test how well and accurately the system functions. The targeted respondents are 80–100 members of farmer groups under the guidance of the Department of Agriculture, Fisheries, and Food Security of Banjarnegara Regency.

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UI/UX Research Method

The UI/UX method is used to evaluate how effectively the expert system impacts farmer groups in consulting about disease symptoms. One of the main issues is the limited number of agricultural extension officers—only five—compared to the large number of assisted farmer groups. As a result, regular meetings between the officers and farmers are not feasible. Additionally, the distance between the farmer group locations and the department office is considerable and requires a long travel time. This research using the UI/UX method assesses the extent to which the system assists farmers in conducting digital consultations.

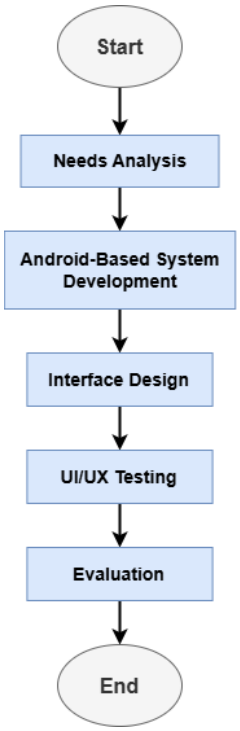


Figure 4. UI/UX Research Method Flowchart

Figure 4 illustrates the flow of the UI/UX research. The user interface (UI) represents a series of iterative decision-making processes that lead to the successful implementation of an interactive tool (Roth, 2017). Meanwhile, user experience (UX) evaluates users' opinions regarding the interface being used. User feedback serves as a valuable note for developers in considering future strategies for expert system design (Luther et al., 2020).

The evaluation will use a questionnaire based on Heuristic Evaluation. Heuristic Evaluation is a method applied in design. It involves assessing a system whether a specification or prototype against established user experience principles (Febrianta Surya Nugraha et al.,

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2017). Table 5 lists the heuristics considered and used as reminders for evaluators regarding potential problem areas.

Table 6. List of Heuristics

No	Heuristic Evaluation
1	Visibility of system status
2	Match between system and the real world
3	User control and freedom
4	Consistency and standards
5	Error prevention
6	Recognition rather than recall
7	Flexibility and efficiency of use
8	Aesthetic and minimalist design
9	System recovery
10	Help and documentation

RESULTS AND DISCUSSION

Data Analysis

In this study, the results of the decision analysis obtained from the Expert System experienced differences between the Certainty Factor and Dempster Shafer methods in displaying the results. Researchers tested one of the diseases with symptoms said yes and definitely. Then the display as a decision as in Figure 5 and Figure 6.



Figure 5. Results of Certainty Factor Method decision data

Figure 5 illustrates the results of the decision data using the Certainty Factor method up to 100%. In the Certainty Factor model, weights of 0 to 1 are given. The first order that appears as a decision on the basis of symptoms is appropriate, namely Tricodiniasis Disease. The decision

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taken is the decision that appears in the first order. While the next order even though 100% indicates that there are the same symptoms in different diseases. Each disease has no specific symptoms, so there are common symptoms that are the same in different diseases.

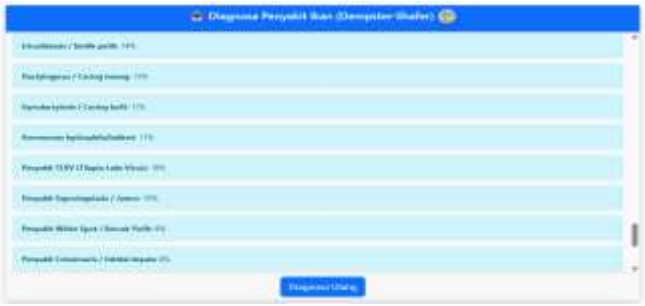


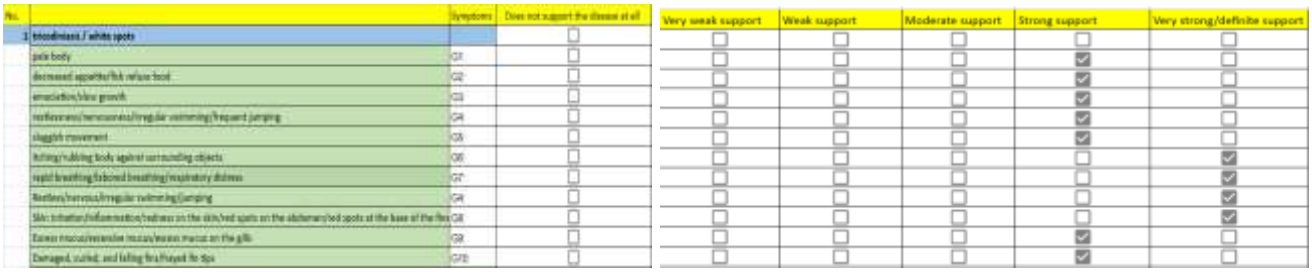
Figure 6. Results of Dempster Shafer Method decision data

Figure 6 illustrates the results of the Dempster Shafer Method decision data with the highest result of 14%. The accuracy of the disease decision from the symptoms obtained is appropriate, namely White Spot disease. The difference in percentage results is caused by weighting. The results of the expert validation recap, the choice of weight falls on strong support (weight 0.8) and very strong support (weight 1). The Dempster Shafer method calculates probabilities. Symptom weights are given a subset of the universe (i.e. the set of possible diseases). Subset weights provide confidence that the information is not specific enough to point to one particular disease.

DISCUSSION

Dempster Shafer Method

The Dempster Shafer method uses the approach of managing uncertainty in decision-making, especially if the symptoms are ambiguous or unclear. The method is quite useful for expert systems to represent a decision on a hypothesis.



No.		Symptoms	Does not support the disease at all	Very weak support	Weak support	Moderate support	Strong support	Very strong/definite support
1	lesions/white spots		☐	☐	☐	☐	☐	☐
	pale body	G1	☐	☐	☐	☐	☑	☐
	decreased appetite/fish refuse food	G2	☐	☐	☐	☐	☑	☐
	emaciation/slow growth	G3	☐	☐	☐	☐	☑	☐
	restlessness/nervousness/irregular swimming/frequent jumping	G4	☐	☐	☐	☐	☑	☐
	sluggish movement	G5	☐	☐	☐	☐	☑	☐
	itching/rubbing body against surrounding objects	G6	☐	☐	☐	☐	☐	☑
	rapid breathing/labored breathing/respiratory distress	G7	☐	☐	☐	☐	☐	☑
	Restless/nervous/irregular swimming/jumping	G4	☐	☐	☐	☐	☐	☑
	Skin: irritation/inflammation/redness on the skin/red spots on the abdomen/red spots at the base of the fins	G8	☐	☐	☐	☐	☐	☑
	Edema mucus/excessive mucus/excess mucus on the gills	G9	☐	☐	☐	☐	☑	☐
	Damaged, curled, and falling fins/frayed fin tips	G10	☐	☐	☐	☐	☑	☐

Figure 7. Sample DS Dataset

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Figure 7 illustrates disease and symptom data based on the weights filled in by the expert. In the figure, the expert selects symptoms G1-G5; G9-G10 with strong support (weight 0.8). Symptoms G6-G8 choose very strong support (weight 1).

Table 7. Combination Weight

Symptoms	Weight	M({P1})	m(ɵ)
G1	0.8	0.8	0.2
G4	0.8	0.8	0.2
G6	1	1	0
G8	1	1	0
G8	1	1	0

From table 7 will be combined pairwise $m_1 \oplus m_2 \oplus m_3$ ... and so on.

The combination of G1 and G4 is as follows:

m1:

m1({P1}) = 0.8

m1(ɵ) = 0.2

m2:

m2({P1}) = 0.8

m2(ɵ) = 0.2

X(m1)	Y(m2)	X ∩ Y	m1(X) × m2(Y)
{P1}	{P1}	{P1}	0.8 × 0.8 = 0.64
{P1}	ɵ	{P1}	0.8 × 0.2 = 0.16
ɵ	{P1}	{P1}	0.2 × 0.8 = 0.16
ɵ	ɵ	ɵ	0.2 × 0.2 = 0.04

K = conflict = 0 (none)Ø

Normalization: 1 / (1 - 0) = 1

m3({P1}) = 0.64 + 0.16 + 0.16 = 0.96

m3(Θ) = 0.04

Merge the above count result with G6 (m({P1}) = 1.0)

m3:

{P1} = 0.96

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~~e~~ = 0.04

m4 (from G6):

{P1} = 1.0

~~e~~ = 0

X	Y	X ∩ Y	m3(X) × m4(Y)
{P1}	{P1}	{P1}	0.96 × 1.0 = 0.96
~~e~~	{P1}	{P1}	0.04 × 1.0 = 0.04

m({P1}) = 0.96 + 0.04 = 1.0

No conflict, ~~e~~ no value.

Merge with G8 (same: m({P1}) = 1.0)

Since m now = 1 for {P1} and the next m is also 1 for {P1}.

The fixed result m({P1}) = 1.0.

Merge with G9 (m({P1}) = 1.0).

So the result remains m({P1}) = 1.0

Final result

Hypothesis	M3 Value
{P1}	1.0
{P2}	0
~~e~~(ignorance)	0

With symptoms G1, G4, G6, G8, and G9, the system is 100% sure that the disease is Trichodiniasis (P1). There is no doubt, as all symptoms support {P1} with high weight and no symptoms support {P2}.

Certainty Factor Method

The Certainty Factor method measures an expert's level of confidence in a fact or rule. In other words, CF indicates how confident the system (or expert) is that a certain symptom leads to a certain disease.

Key components in CF:

1. CF (User): The confidence level of the user in the symptoms they experience (on a scale of 0 to 1).
2. CF (Expert): The expert's confidence level that a symptom is related to a disease (also on a scale of 0 to 1).



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3. CF (Combined): If there is more than one symptom for one disease, the total CF value is calculated by the CF merging formula.

In this section we will take data from filling in the expert according to Figure 4.4.

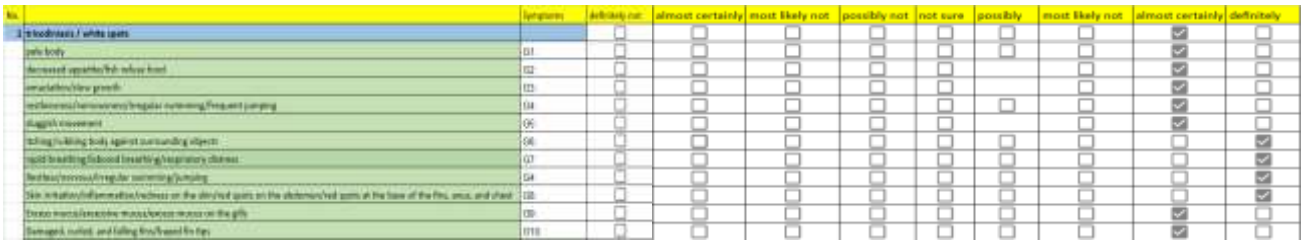


Figure 8. Sample CF Dataset

In Figure 4.4 symptoms G1 - G5; G9 - G10 indicate almost certain (weight 0.8) and symptoms G6 - G8 indicate certain (weight 1). CF calculation results from Cfuser x CFexpert. If there is more than one symptom supporting the same diagnosis, the merging is done as follows:

For two CFs:

Combined CF = CF1 + CF2 × (1-CF1)

Symptom Code	CF Expert
G6	0.6
G7	0.7
G8	0.8

Calculation of each symptom

Symptom Code	CF Expert
G6	0.6 x 1.0 = 0.60
G7	0.7 x 1.0 = 0.70
G8	0.8 x 1.0 = 0.80

Calculate the combined CF Combined

G6 + G7

CF(67) = 0.60 + 0.70 x (1 -0.60) = 0.88

CF(67) + G8

CF(678) = 0.88 + 0.80 x (1 - 0.88) = 0.976

Thus the combined result of symptoms with a weight of 1 is 0.976. indicating full confidence in Trichodiniasis disease.

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CONCLUSION

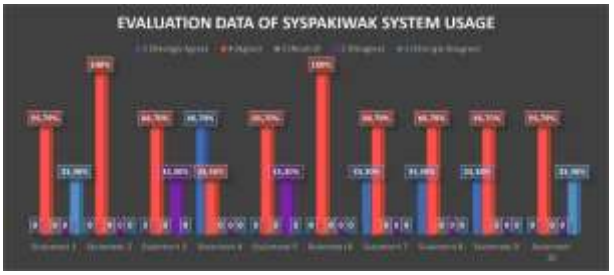


Figure 9. Questionnaire Results for Statements 1 through 10

Figure 9 displays the final results of the 10-question heuristic method questionnaire. Among these questions, statements 2 and 6 concerning system compatibility with real-world applications and ease of memorization received 100% agreement. The remaining statements showed 66.70% agreement. Thus, the average user approval rate for this system was calculated at 73.36%.

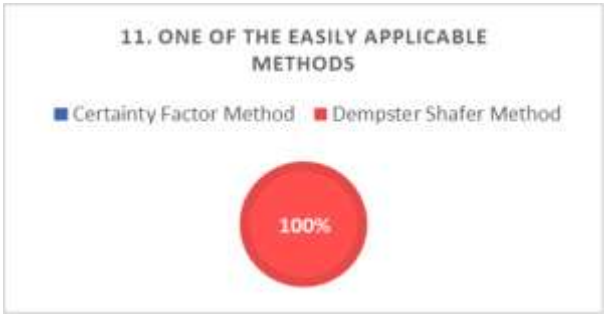


Figure 10. Results of User-Chosen Methods

Figure 10 displays user preference data regarding ease of use between the Certainty Factor and Dempster-Shafer methods, with 100% of respondents selecting the Dempster-Shafer method.

Although this section cannot yet be considered a conclusion, the researcher concludes this report with a summary of the progress achieved so far. Several key advancements have been observed in this research activity:

1. High Enthusiasm from the Agriculture, Fisheries, and Food Security Office of Banjarnegara Regency. The office showed strong support, as they felt greatly assisted by the Android-based expert system. This system helps farmers and agricultural extension workers collaborate more effectively.

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2. High Enthusiasm from Fish Farmers. Fish breeders demonstrated a strong need for up-to-date information on fish diseases that cause mortality. They require both physical assistance and knowledge-based support.
3. User Feedback from Questionnaires
   a. 73.36% of users agreed to adopt the Expert System as a consultation tool for fish disease detection.
   b. The Dempster-Shafer method was preferred due to its ease of use and convenience, with 100% of users selecting it.

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