Utilization Of The Certainty Factor Method To Improve Diagnostic Accuracy In An Expert System For Diseases And Pests Of The Sugar Palm (Arenga Pinnata)

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Abstract: The sugar palm (*Arenga pinnata*) is an economically valuable plant with various applications in food, construction, and biofuel production. However, its cultivation is often affected by diseases and pests that can reduce productivity and quality. This study aims to develop an expert system for diagnosing diseases and pests in sugar palm trees, using the Certainty Factor method to enhance diagnostic accuracy. The Certainty Factor method enables the system to incorporate uncertainty in expert knowledge by quantifying confidence levels for each diagnosis. By applying this method, the expert system provides more accurate and reliable diagnostic results, especially in cases where symptoms are ambiguous or overlap among different diseases. Designed as a web-based application, the system is easily accessible to farmers and agricultural professionals. Testing results indicate that the use of the Certainty Factor method significantly improves diagnostic accuracy, making this tool valuable for better disease and pest management in sugar palm cultivation.

INTRODUCTION

The sugar palm (*Arenga pinnata*) is a highly versatile tropical plant with considerable economic significance(Yulia et al., 2024), widely cultivated across Southeast Asia, especially in Indonesia (Endriatno, 2024). Its sap is processed to make palm sugar, while its fibers and leaves are used in construction and craft, and its oil and starch are valuable in biofuel and food industries(Surya Adji Syahputra et al., 2012). However, the cultivation of sugar palm faces persistent challenges due to various diseases and pests that can drastically reduce both yield and quality (Pertanian et al., n.d.). Effective management of these threats is essential for maintaining productivity and supporting the agricultural economy (Hadi et al., 2024).

Traditionally, diagnosing diseases and pests in sugar palm requires substantial expertise in plant pathology and entomology. Yet, access to trained experts is often limited in rural agricultural regions, where farmers may struggle to identify specific diseases or pest infestations accurately. This can lead to misdiagnoses, ineffective treatments, and, ultimately, further crop loss (Silvia Dewi et al., n.d.). There is a pressing need for an accessible diagnostic tool that empowers farmers with accurate and reliable information to support effective decision-making in pest and disease management.

Expert systems have proven to be a valuable tool in various fields for capturing(Schaefer^ & Pferdmenges^, 1994), organizing, and replicating expert knowledge(Batubara et al., 2018). In agriculture, expert systems are designed to mimic the decision-making processes of human specialists, offering diagnostic support by evaluating symptoms and applying decision rules (R. E. Putri et al., 2020). In cases of plant disease diagnosis, where symptoms can be ambiguous or overlap across different issues, incorporating a method to handle uncertainty is crucial(Ferdinal et al., 2022). This is where the Certainty Factor (CF) method becomes highly useful. The CF method allows the system to quantify the degree of confidence in each possible diagnosis, thus enabling more accurate results even under uncertainty(Sidiq Purnomo, n.d.).

This study aims to develop and implement a web-based expert (Yusman et al., 2022) system for diagnosing diseases and pest infestations in sugar palm using the Certainty Factor method. By leveraging this approach, the system can incorporate the nuances of expert knowledge, assigning confidence levels to each diagnosis based on symptom analysis. Such a system would be accessible to both farmers and agricultural professionals, providing a practical, reliable, and user-friendly solution for field-based diagnosis.

The objectives of this study include designing an efficient diagnostic model based on the CF method, developing the web-based interface to ensure accessibility (Manurung et al., 2024), and evaluating the system's performance in terms of diagnostic accuracy and user satisfaction. Ultimately, this research seeks to contribute to improved disease and pest management practices in sugar palm cultivation, thereby supporting sustainable agricultural practices and enhancing productivity in affected regions(N. A. Putri & Hartanto, 2020).

RESEARCH METHODS

This research consists of several systematic and structured stages, each designed to develop an effective web-based expert system for diagnosing diseases and pests in the sugar palm (*Arenga pinnata*) using the Certainty Factor method. Each stage focuses on important aspects of the research process, ranging from information gathering and understanding user needs to system design, development, testing, and implementation :

1. **Literature Review**

   Conduct a comprehensive review of existing research on diseases and pests affecting sugar palm (*Arenga pinnata*) and current diagnostic methods. Identify gaps in existing expert systems and their application in agricultural diagnostics.

2. **Needs Assessment**

   Engage with farmers and agricultural experts through surveys and interviews to understand their diagnostic needs and challenges. Determine the desired features and usability requirements for the web-based expert system.

3. **System Design**

   Develop a detailed system architecture, including the database, user interface, and algorithm for disease and pest diagnosis. Create a knowledge base that encompasses symptoms, diseases, and pests, along with corresponding Certainty Factor values to quantify uncertainty.

4. **System Development**

   Implement the backend logic that applies the Certainty Factor method for diagnostic purposes. Develop the frontend user interface, ensuring it is intuitive, responsive, and accessible across devices.

5. **System Testing**

   Conduct unit and integration testing to identify and resolve any software bugs or issues. Perform usability testing with target users to gather feedback on system functionality and ease of use. Validate the diagnostic accuracy by comparing system outputs with expert diagnoses in varied scenarios.

6. **Evaluation and Optimization**

   Analyze user feedback and system performance data to identify areas for improvement. Refine the knowledge base and algorithms based on evaluation results to enhance the system's effectiveness and accuracy.

7. **Implementation and Dissemination**

   Launch the expert system for public use, ensuring accessibility for farmers and agricultural professionals. Conduct training sessions and workshops to educate users on how to effectively use the system. Publish research findings in relevant academic journals and present at conferences to share knowledge and promote the system.

8. **Monitoring and Maintenance**

Regularly collect feedback from users and monitor system performance to ensure its ongoing effectiveness. Update the knowledge base and software components as new information becomes available and address any technical issues promptly.

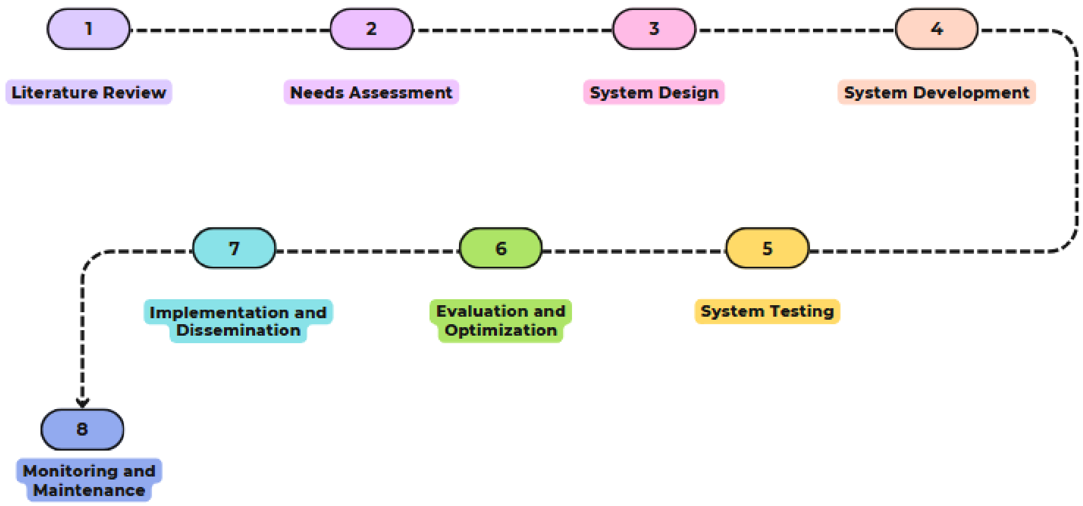

Figure 1. Research Stages

RESULTS AND DISCUSSION

Before designing a knowledge base, a knowledge acquisition process was carried out by collecting facts through interviews with experts.

1. The disease criteria data for the sugar palm

The disease criteria data for the sugar palm trees are based on cases previously experienced by farmers on plantations. In coding, the author assigns 'P' to represent disease criteria in sugar palm, starting sequentially from 'P01' to 'P06.' This knowledge and data are presented in the following table.

Table 1. Disease Table

Kode Penyakit	Nama Penyakit
P01	Basal Stem Rot
P02	Leaf Spot Disease
P03	Root Rot
P04	Leaf Rust
P05	Pink Disease
P06	Bacterial Wilt

2. Symptom Data

The symptom criteria data for the sugar palm tree are based on observed symptoms in the tree. In coding, the author assigns 'G' to represent symptom criteria in sugar palm, starting sequentially from 'G01' to 'G18.' This knowledge and data are presented in the following table:

Table 2. The Symptom Table

Symptom Code	The Symptom
G01	Leaves turn yellow and wilt.
G02	The lower part of the stem rots and often shows white or brown fungi.
G03	Brown or black spots appear on the leaves.
G04	Infected leaves may dry up and fall off.
G05	Root rot leads to yellowing and wilting leaves.
G06	Plant growth is stunted.
G07	Yellow or orange spots appear on the leaf surface.
G08	Leaves may dry and fall off if the infection is severe.
G09	A pink or white layer appears on stems and branches.
G10	Infected parts may die, causing serious damage to the tree.
G11	Leaves turn yellow and wilt, starting from the lower leaves.
G12	Stems and roots exude a brown slime.
G13	The base of the stem turns black.
G14	Peeling of the bark.
G15	Reduced fruit production.
G16	Root rot.
G17	Decrease in leaf production.
G18	Decline in fruit quality.

3. Rule Data

Created to help the researcher organize the data more effectively, ensuring that it aligns with the knowledge base obtained from sugar palm experts. The structure can be seen in the table below:

Table 3. Rule Table

No.	**Rule**	**Symptom**	**Disease**
1	R1	IF G01, G02, G03, G13, G14	Then P01
2	R2	IF G04, G05, G15, G16	Then P02
3	R3	IF G07, G08, G13, G17, G18	Then P03
4	R4	IF G05, G07, G09, G10, G11, G17	Then P04
5	R5	IF G08, G09, G11, G18	Then P05
6	R6	IF G06, G10, G12, G14, G15, G16	Then P06

4. Decision Table

Based on the knowledge obtained from experts, a decision table is constructed as the foundation for building the inference engine.

Tabel 4. Decision Table

Symptom	Disease					
	P01	P02	P03	P04	P05	P06
G01	√	-	-	-	-	-
G02	√	-	-	-	-	-
G03	√	-	-	-	-	-
G04	-	√	-	-	-	-
G05	-	√	-	√	-	-
G06	-	-	-	-	-	√
G07	-	-	√	√	-	-
G08	-	-	√	-	√	-
G09	-	-	-	√	√	-
G10	-	-	-	√	-	√
G11	-	-	-	√	√	-
G12	-	-	-	-	-	√
G13	√	-	√	-	-	-
G14	√	-	-	-	-	√
G15	-	√	-	-	-	√
G16	-	√	-	-	-	√
G17	-	-	√	√	-	-
G18	-	-	√	-	√	-

Based on the table above, the symptoms of diseases in sugar palm plants and the criteria for each disease are explained. In this expert system for diseases in sugar palm, there are symptoms or characteristics used to provide solutions. In the system's consultation session, the user is given answer options, with eight answer choices, each assigned a weight as follows:

Table 5. Characteristics of Fact

Fakta		**Certainty Term**	**Nilai CF**
G01	*Evidence*	Certain	CF = 1,0
G02	*Evidence*	Almost Certain	CF = 0,80
G03	*Evidence*	Very Likely	CF = 0,70
G05	*Evidence*	Possible	CF = 0,60
G08	*Evidence*	Certain	CF = 1,0
G09	*Evidence*	Almost Certain	CF = 0,80
G10	*Evidence*	Very Likely	CF = 0,70
G13	*Evidence*	Very Likely	CF = 0,70
G16	*Evidence*	Certain	CF = 1,0
G17	*Evidence*	Very Likely	CF = 0,70
G18	*Evidence*	Possible	CF = 0,60

After characteristic facts are obtained from the user, the next process is for the system to check the characteristics within the rules. The rules that will be processed based on the dialogue between the user and the system can be seen in the table below:

Tabel 6. CF Values of Fulfilled Rules

NO.	**IF**	**THEN**	**NILAI CF**
1.	G01 AND G02 AND G03	**P1**	**0,75**
2.	G01 AND G02	**P1**	**0,5**
3.	G02 AND G03 AND G08	**P4**	**0,6**
4.	G02 AND G03	**P4**	**0,5**
5.	G03 AND G08	**P5**	**0.50**
6.	G30 AND G31 AND G32	**P7**	**1**
7.	G30 AND G31	**P7**	**0,85**

After the rules are identified, the next step is to calculate the value of the Hypothesis (new fact) using the Certainty Factor formula, which is: $CF(A \text{ AND } B) = \text{Min}(CF(A), CF(B)) * CF(rule)$. The calculations can be seen as follows:

Rule 2 = IF G01 (1,0) and G02 (0,80) and G03 (0,70) Then P1 (CF = 0,75)
CF2 (P1.G01 ∩ G02 ∩ G03)
= Min[1,0 ; 0,80 ; 0,70] * 0,75
= 0,52
Fakta Baru :
P1 Hypothesis CF = 0,52

Rule 3 = IF G01 (1,0) and G02 (0,80) Then P001 (CF = 0,50)
CF3 (P1.G01 ∩ G02)
= Min[1,0 ; 0,80] * 0,50
= 0,40
Fakta Baru :
P1 Hypothesis CF = 0,40

Rule 6 = IF G02 (0,80) and G03 (0,70) and G08 (1,0) Then P4 (CF = 0,60)
CF21 (P4.G02 ∩ G03 ∩ G08)
= Min[0,80 ; 0,70 ; 1,0] * 0,60
= 0,42
Fakta Baru :
P4 Hypothesis CF = 0,42

Rule 9 = IF G02 (0,80) and G03 (0,70) Then P4 (CF = 0,50)
CF22 (P4.G02 ∩ G03)
= Min[0,80 ; 0,70] * 0,50
= 0,35
Fakta Baru :
P4 Hypothesis CF = 0,35

Rule 12= IF G03 (0,80) and G08 (1,0) Then P5 (CF = 0,50)

CF25 (P5.G03 ∩ G08)

= Min[0,80 ; 1,0] * 0,50

= 0,40

Fakta Baru :

P5 Hypothesis CF = 0,40

Rule 16= IF G30 (0,80) and G31 (0,60) and G32 (0,1) Then P7 (CF = 1,0)

CF34 (P7.G30 ∩ G31 ∩ G32)

= Min[0,80 ; 0,60 ; 0,1] * 1,0

= 0,10

Fakta Baru :

P7 Hypothesis CF = 0,10

Rule 18= IF G30 (0,80) and G31 (0,60) Then P7 (CF = 0,85)

CF35 (P7.G30 ∩ G31)

= Min[0,80 ; 0,60] * 0,85

= 0,51

Fakta Baru :

P7 Hypothesis CF = 0,51

After the calculations are completed for each selected rule, the resulting hypothesis or new facts are presented in the table below:

Tabel 7. New of Fact

New of Fact		**CF Value**
P1	*Hypothesis*	0,52
P1	*Hypothesis*	0,40
P4	*Hypothesis*	0,42
P4	*Hypothesis*	0,35
P5	*Hypothesis*	0,40
P7	*Hypothesis*	0,10
P7	*Hypothesis*	0,51

From the table of new facts above, we can see that there are identical hypothesis results. The next step is to calculate the combined CF (combination) using the formula CF1 + CF2 * (1 - CF1). In other words, this involves summing each value of new facts for each type, then multiplying the total sum by one minus the maximum value of the new facts for each type. Once the result is obtained, it is multiplied by 100%.

1. (CF2 + CF3) * (1 – CF3)
= (0,52 + 0,40) * (1 – 0,40)
= 0,92 * 0,60
= 0,552
Combination Result Multiplied By 100 % = 0,552 * 100 % = 55,2 %
2. (CF21+CF22)*(1 – CF21)
= (0,42+0,35) * (1 – 0,42)
= 0,77 * 0,58
= 0,4466
Combination Result Multiplied By 100 % = 0,4466 * 100 % = 44,66 %
3. (CF25) * (1 – CF25)
= (0,40) * (1 – 0,40)
= 0,40 * 0,60
= 0,240
Combination Result Multiplied By 100 % = 0,240 * 100 % = 24 %
4. (CF34 + CF35) * (1 – CF35)
= (0,10 + 0,51) * (1 – 0,51)
= 0,61 * 0,49
= 0,2989
Combination Result Multiplied By 100 % = 0,2989 * 100 % = 29,89

After the combination result is obtained, to facilitate the user in viewing the results, a results table can be created as follows:

Tabel 8. Combination Result

Kode Penyakit	**Jenis Penyakit**	***Rule***	**Nilai CF**	**Hasil Kombinasi**
P1	(*Basal Stem Rot*)	*Rule* 2	0,52	55,20%
P1	(*Basal Stem Rot*)	*Rule 3*	0,40	
P4	(*Leaf Rust*)	*Rule 4*	0,42	44,66%
P4	(*Leaf Rust*)	*Rule 5*	0,35	
P5	(*Pink Disease*)	*Rule 7*	0,40	24,00%

From the combination result table and the CF values above, a new table can be created, which outlines the sequence of combination results and CF values from the largest to the smallest.

Tabel 9. Order of Combination Result Values and CF Values

Kode Penyakit	Jenis Penyakit	Hasil Kombinasi
P1	(*Basal Stem Rot*)	55,20%
P4	(*Leaf Rust*)	44,66%
P5	(*Pink Disease*)	24,00%

The conclusion from the table of the order of combination result values and CF values indicates that the type of disease affecting the user's sugar palm tree is Basal Stem Rot, with a certainty level of 0.552 or 55.2%.

CONCLUSION

In this study, we developed a web-based expert system designed to diagnose diseases and pests affecting sugar palm (*Arenga pinnata*) using the Certainty Factor method. The systematic approach taken throughout the research, from knowledge acquisition to rule establishment and hypothesis evaluation, has demonstrated the potential for effectively identifying and diagnosing plant health issues. The results indicate that the expert system can provide valuable insights for users, enhancing their ability to manage diseases in sugar palms. Overall, this expert system serves as a practical tool to support farmers and agricultural professionals in improving crop management and promoting sustainable agricultural practices.

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