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Expert System Design for Laying Hen Disease Diagnosis Using Forward Chaining and Certainty Factor

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ABSTRACT

Laying hens are a crucial part of the poultry industry, significantly contributing to the fulfillment of animal protein needs. However, the prevalence of various diseases remains a primary threat that causes a drastic decline in egg production and high mortality rates. The delay in diagnosis, exacerbated by the limited availability of veterinary specialists in rural areas, emphasizes the need for an accessible diagnostic tool. This research aims to develop a web-based expert system capable of diagnosing 11 types of laying hen diseases based on 27 observable symptoms. The system implements the Forward Chaining method as an inference engine to systematically trace disease rules starting from the user-inputted symptoms. Furthermore, the Certainty Factor (CF) method is integrated to calculate the confidence level of the diagnosis, utilizing the Measure of Belief (MB) and Measure of Disbelief (MD) values provided by an expert veterinarian. The system was tested using Blackbox testing for functional validation, which yielded 100% functionality. Furthermore, accuracy testing across 18 real-world test cases demonstrated that the system achieved an accuracy rate of 77.78%, with 14 cases perfectly matching the expert's diagnosis. This expert system proves to be highly effective in assisting farmers in performing early disease identification and taking timely preventive measures.

1. Introduction

Laying hens are commercial poultry that play a crucial role in fulfilling the community's need for animal protein through the production of high-quality eggs (Daroch & Kumar, 2025), with Asia accounting for over 70% of the growth in global egg production (Hartcher et al., 2023). In Indonesia, laying hen farming is highly favored by rural communities due to high market demand and lower production costs compared to other animal protein sources, as well as providing a significant income contribution for farmers (Sutiani et al., 2025; Sari & Mardhiah, 2025). However, this livestock sector is vulnerable to various production and health risks that can directly impact business continuity (Toriqfai & Siswahyudianto, 2022).

The health of laying hens is often threatened by infectious diseases such as Avian Influenza (AI) and Newcastle Disease (ND). Based on observations at a farm in a village in Tabanan Regency, delays in diagnosing and treating a disease such as infections that cause a drastic drop in egg production within a few days have become a major problem. This constraint is exacerbated by farmers' lack of access to poultry veterinary specialists in rural areas. On the other hand, farmers often rely solely on visual observation of clinical symptoms but lack sufficient medical understanding to conclude the specific type of disease attacking their livestock.

As a solution to these problems, an expert system capable of mimicking the mindset and expertise of a veterinarian is needed. This study aims to develop an interactive web-based expert system to diagnose 11 types of diseases in laying hens. Through the integration of forward reasoning computational methods and certainty theory, this system is designed to detect diseases as early as possible, provide treatment recommendations, and ultimately prevent greater economic losses for farmers.

2. Literatur Review

Several previous studies have proven the effectiveness of expert systems in the livestock and agricultural domains. Research conducted by Hasanah and Durahman (2024) built an expert system using the pure Forward Chaining method to diagnose laying hen diseases. This method proved effective as an initial diagnostic tool based on known symptom facts. On the other hand, Amriyansah et al. (2024) also applied Forward Chaining in a web-based system to diagnose 10 types of poultry diseases with high operational accuracy, providing preventive education for farmers. The application of pure Forward Chaining has also proven effective in other domains, such as the diagnosis of cattle diseases (Azmi & Ismail, 2023) and human eye diseases (Muafi et al., 2020).

In addressing the aspect of uncertainty in medical observations, hybrid approaches are often employed. Arsita et al. (2023) designed an expert system for aloe vera plants that combined Forward Chaining with Certainty Factor, achieving a diagnostic confidence level of 84%. Similarly, Andika and Wulandari (2024) applied a combination of the same methods for betta fish diseases, where this combination not only traced rules logically but also calculated a certainty probability of 83.3%. A similar approach was also applied to an expert system for chili pests and diseases (Jamaludin et al., 2024) as well as the diagnosis of allergic diseases in children using a web-based Certainty Factor method (Irsyada et al., 2024), both of which demonstrated an increase in diagnostic reliability compared to single methods.

A research gap exists among these previous studies. Most expert systems for laying hens solely use pure Forward Chaining without accommodating the doubts or uncertainties of farmers when observing symptoms in the field. Therefore, this study combines Forward Chaining as a logical inference engine with Certainty Factor to calculate the degree of certainty in diagnosing laying hen diseases, utilizing direct weights obtained from the expertise of veterinary specialists.

3. Research Method

This research was conducted through systematic stages, starting from data collection to system testing. Primary data was collected through in-depth interviews with a poultry veterinary expert, drh. Anak Agung Raka Isyani Dewi, S.Kh., and farmers in Mengesta Village, Tabanan Regency. Secondary data was gathered from literature reviews and farm medical records.

Knowledge Representation and Inference Engine

The knowledge base was constructed using 11 disease types and 27 symptom data points validated by an expert. The inference method utilized is Forward Chaining. This method triggers the evaluation of a set of rules (Rule Base) in the form of IF-THEN action conditions. The symptom data inputted by the user is processed within the working memory; if the premise is fulfilled, the system will draw a conclusion regarding the type of disease experienced by the livestock.

Certainty Factor (CF)

To accommodate uncertainty in the diagnostic process, the Certainty Factor method is employed. The expert assigns Measure of Belief (MB) and Measure of Disbelief (MD) values for each symptom and disease relationship. These values range from -1.0 to 1.0. This Certainty Factor approach continues to be further developed, for instance, through extensions based on neutrosophic logic to handle more complex uncertainties (Paraskevas, 2024).

$$CF[H,E] = MB[H,E] - MD[H,E] \quad (1)$$

If there is more than one symptom referring to the same disease, the system will perform a Combined CF (CF Combine) calculation using the following equation:

$$CF(x,y) = CF(x) + (CF(y) \times (1 - CF(x))) \quad (2)$$

System Design and Evaluation

The system was modeled using the Unified Modeling Language (UML), including Use Case, Activity, and Class Diagrams. The web-based system was implemented using PHP and MySQL. Testing was conducted through Blackbox Testing to validate the user interface (UI) functionality, as well as Accuracy Testing, which compared the system's diagnostic outputs with the direct medical examination results provided by the veterinary expert.

Table 1. Certainty Term Score

Certainty Term	Nilai Certainty Factor (CF)
Not Certain	0.00
Slightly Certain	0.20
Less Certain	0.40
Moderately Certain	0.60
Certain	0.80
Very Certain	1.00

Flowchart of System

The flowchart illustrates the workflow of a chicken disease diagnosis system based on a rule-based expert system using the forward chaining method and the Certainty Factor (CF) approach. The process begins at the *Start* stage, where the system displays a menu for entering disease symptoms. The user then selects or enters the symptoms observed in the chicken based on its condition. Next, the system checks whether the entered symptoms are valid. If the input is invalid, the process returns to the symptom input menu, allowing the user to re-enter the symptoms. If the input is valid, the system proceeds to match the symptoms with the rules stored in the *knowledge base* using rule-based reasoning. The next stage applies the forward chaining method to establish relationships between the entered symptoms and relevant diseases. Based on these relationships, the system calculates the Certainty Factor (CF) value for each potential disease. The CF value represents the level of confidence in the relationship between the observed symptoms and each disease. After the calculation, the system displays the validation results based on the most likely disease. It also provides a list of possible diseases along with their respective CF values as alternative diagnostic information. Finally, the disease with the highest CF value is selected as the main diagnosis and presented to the user. The diagnostic process then ends.

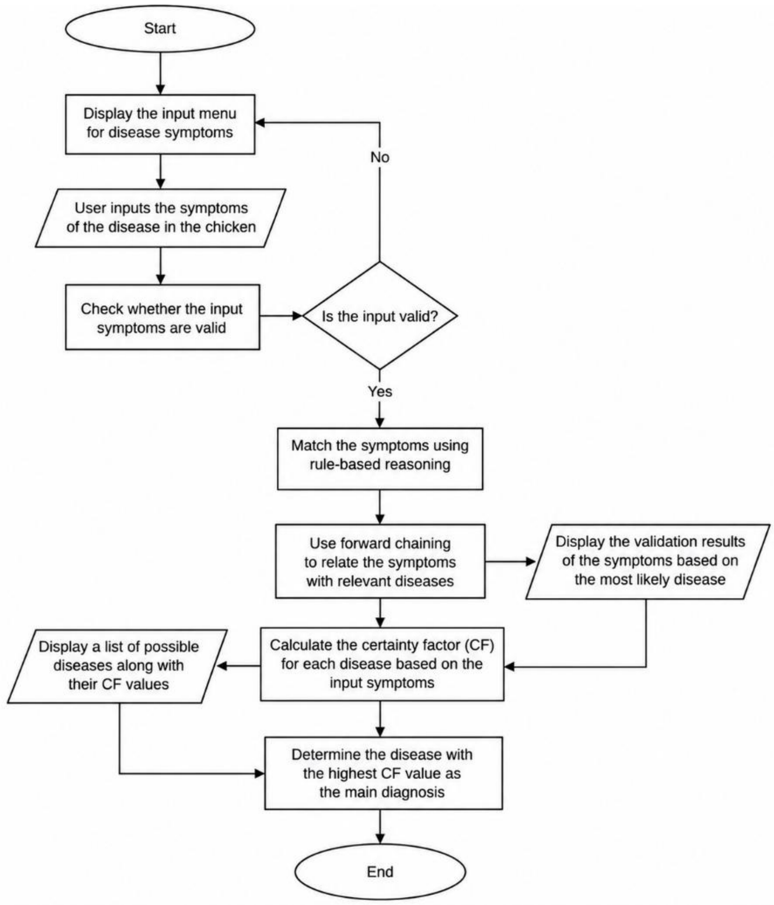

Fig.1 Flowchart of System

In Fig. 2 presents the use case diagram utilized to design the system. As depicted in the use case diagram, there are two actors involved in the system, namely the admin and the farmer (peternak).

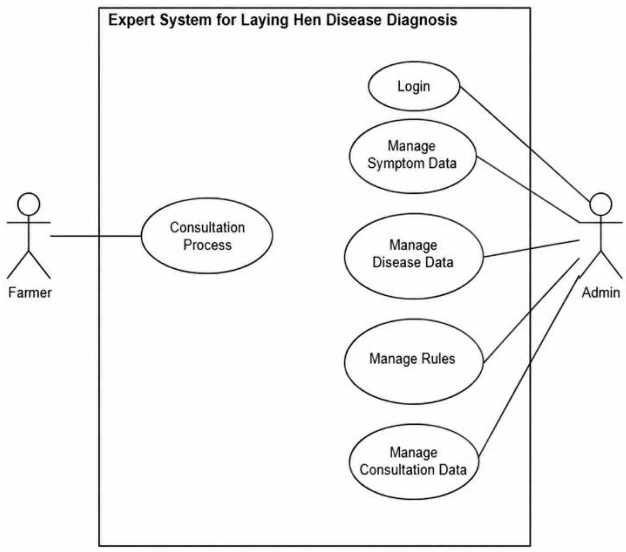

Fig.2 Usecase Diagram

4. Result and Discussions

System Overview

The system developed in this study is an expert system designed to assist poultry farmers in diagnosing diseases in laying hens based on observed symptoms. This system uses the Forward Chaining method to trace facts from the entered symptoms to generate a conclusion regarding the possible diseases affecting the hens. In addition, the system also applies the Certainty Factor method to provide a level of certainty regarding the diagnosis results based on the confidence weight of each symptom. With this system, farmers can easily identify diseases early on, take appropriate treatment measures, and minimize the negative impact on egg productivity. This system was developed as a web-based application so that it can be easily accessed by farmers anytime and anywhere.

Fig. 3 System Overview

Implementation of Diagnosis Calculation

Cleaning removed 15,169 rows, or 5.69% of the initial dataset. At the IDR 5,000,000 minimum-utility threshold, TWU screening retained 2,858 items. Utility-list calculation then produced 57 qualifying one-itemsets and 1,270 qualifying two-itemsets. During association analysis, 2% minimum support generated 248 frequent itemsets, 10% minimum confidence retained 77 rules, and lift greater than 1 retained 64 rules. Matching every criterion produced 23 final rules. Table 1 summarizes the successive processing and selection results.

The research results encompass the implementation of diagnostic calculations, interface design, and validation of the system evaluation. The successfully compiled knowledge base includes crucial diseases such as Newcastle Disease, Avian Influenza, Salmonellosis, Coccidiosis, and Fowl Pox.

The inference engine mechanism was tested using field case simulations. For example, a user inputs the following symptoms: difficulty breathing with a user confidence value of 0.80, snoring sounds during breathing (0.60), sudden death (1.00), swelling of the head and neck (0.40), and decreased egg production (0.20).

In the evaluation of the Avian Influenza (AI) rule, the system calculates the Local CF based on the expert's weight (MB - MD) and multiplies it by the user's input weight. Subsequently, the CF is accumulated. The results of the iterative calculations within the inference engine show that the combined CF for Avian Influenza reached the highest value of 0.9747 or 97.47%, making it the primary diagnostic conclusion.

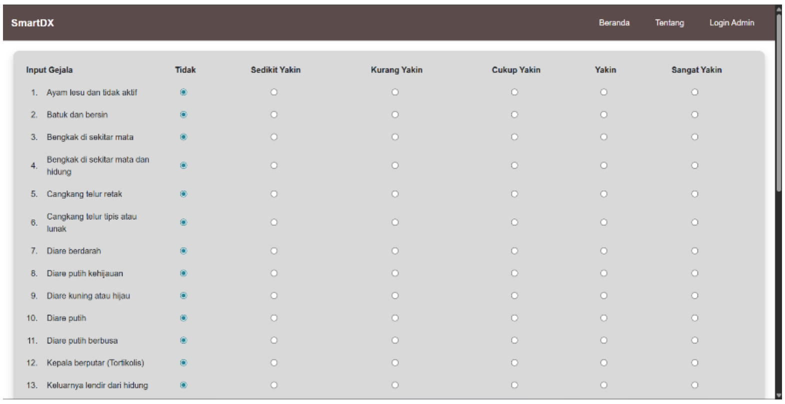

Fig.4 Symptom Input User Interface

Fig. 4 illustrates the symptom input interface, designed to enable users to input the symptoms experienced by the laying hens. This interface displays symptoms retrieved from the data_gejala table, alongside the user's confidence levels. There are several confidence levels provided, namely: no, slightly certain, less certain, quite certain, certain, and very certain. The user's confidence values obtained from these levels are subsequently processed by the system to generate a diagnosis using the Certainty Factor calculation formula.

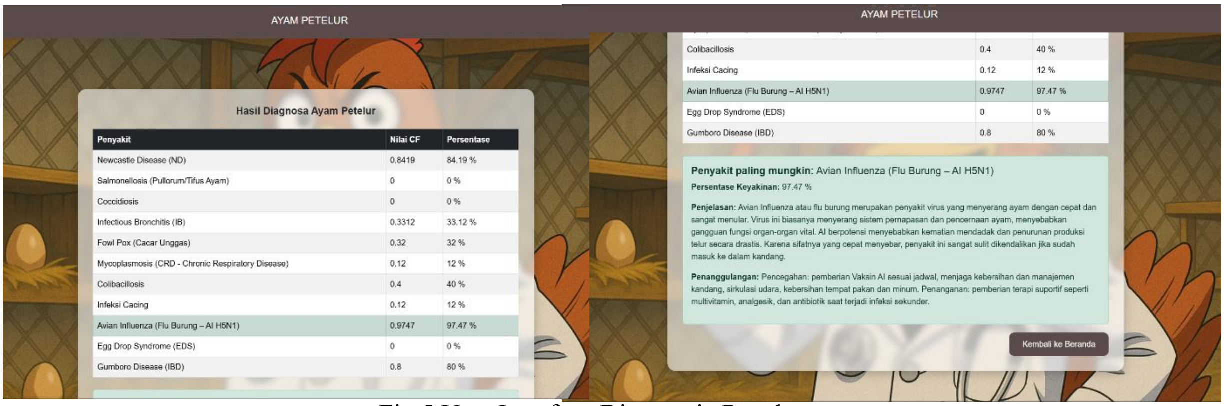

Fig.5 User Interface Diagnostic Results

Fig. 5 depicts the system interface for displaying the diagnostic results. This page aims to present the diagnosis percentages resulting from the inputted symptom confidence levels for the laying hens. The system details the disease with the highest percentage and provides its corresponding treatment recommendations, allowing farmers to take appropriate measures as soon as possible.

Testing and Evaluation

Blackbox testing confirmed that all system functionalities (such as the symptom input form, rule base management by the admin, and the calculation process) operate validly and stably without systematic errors. Accuracy testing was conducted on 18 random medical record history cases (comprising samples from farmers, researchers, and experts).

Out of these 18 tests, the system's output demonstrated conformity with the expert's manual analysis in 14 cases. The accuracy calculation can be seen in the following equation:

$$Accuracy = (14/18) \times 100\% = 77.78\% \quad (3)$$

This accuracy result of 77.78% proves that the Forward Chaining and Certainty Factor methods are capable of reliably and adaptively handling the uncertainty of input data from non-medical farmers, providing an output that highly correlates with the clinical perspective of professional veterinarians.

5. Conclusion

This research successfully designed and implemented a web-based expert system for the diagnosis of laying hen diseases. The use of the Forward Chaining method is highly efficient in selecting diagnostic rules based on observational symptoms, while the Certainty Factor method is crucial in addressing farmers' uncertainty and generating precise diagnoses with specific probabilities. Functional testing ran 100% optimally, and the expert evaluation demonstrated an accuracy rate of 77.78% out of 18 test cases. For future work, it is recommended to expand the knowledge base by including more disease variants and to integrate the system with a spatial database for mapping the geographical distribution of diseases.

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