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Expert System For Early Diagnosis Of Dog Skin Diseases Using The Dempster-Shafer Method

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ABSTRACT
This study developed a web-based expert system for the early diagnosis of canine skin diseases, utilizing the Dempster-Shafer method. The close bond between humans and dogs, the high rate of dog ownership, and the prevalence of skin diseases among dogs in Bali Province highlight the need for an effective solution, particularly given dog owners' limited knowledge of diagnosis and treatment options. The research involved interviews with veterinary experts and an extensive literature review, resulting in the creation of a knowledge base comprising 12 common canine skin diseases and 23 associated symptoms. The Dempster-Shafer method was employed to address uncertainty in decision-making by calculating belief and plausibility values, ensuring accurate diagnostic results. The system's database design enables efficient management of disease, symptom, patient, and diagnosis information. Testing demonstrated an accuracy rate of 86.36% and a user satisfaction score of 89.09%, indicating that the system is both reliable and user-friendly. This expert system provides a practical tool for dog owners in Bali, supporting early diagnosis and appropriate management of canine skin diseases.

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INTRODUCTION

The dog population in Bali is notably high, with an estimated 74,000 dogs, and most households owning one or two [1]. This situation underscores the importance of focusing on the health and welfare of dogs in Bali, particularly regarding their physical well-being. Healthy dogs typically exhibit optimal physical appearance [2]. However, neglect in maintaining and caring for their health can lead to severe consequences, including life-threatening conditions. Like humans, dogs are susceptible to various health issues, with skin diseases being among the most common. Skin diseases not only cause distress to the animals but also to their owners, as these conditions can sometimes be transmitted to humans due to close contact between dogs and their owners [3].

Skin diseases can affect dogs of all ages, from puppies to adults, and arise from various causes, including hereditary factors and external infections such as viruses, bacteria, and fungi [4]. A significant challenge for dog owners is the lack of knowledge about skin diseases

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and their management, compounded by limited access to veterinary clinics. These factors often result in inadequate treatment, which can exacerbate the condition [5].

Research by N. Firnateris (2022) found that out of 341 animal patients, including dogs, cats, and other species, 37% of the monthly cases were dogs, with the majority presenting with skin diseases (dermatitis) [6]. Another study conducted in Bali by Komang Andika Purnama, titled Histopathological Analysis of Dog Skin with Dermatitis, revealed that dogs in Denpasar, Gianyar, Badung, and Tabanan are commonly diagnosed with skin diseases. The study showed that 60% of affected dogs were young, 67% had long hair, 73% were male, and 73% were local village dogs [7]. Further histopathological analysis indicated that 33% of the dogs experienced moderate dermatitis, while 67% suffered from severe dermatitis. Dogs with these conditions often face recurrent infections caused by various infectious agents.

Skin diseases in dogs frequently present with similar symptoms, making accurate diagnosis essential for effective treatment. Timely and precise diagnosis is critical to preventing further complications and ensuring proper care [6]. Early identification and management can improve recovery rates and reduce the risk of prolonged suffering and disease progression.

Advances in technology have contributed to significant developments in veterinary medicine, including the creation of expert systems. These systems are typically designed to operate through a consultation process, where they ask patients about their symptoms to diagnose diseases. They must function quickly and efficiently while providing accurate initial diagnoses to ensure appropriate follow-up actions can be taken [8]. These systems can provide early diagnosis of canine skin diseases, addressing the challenges faced by dog owners. This study aims to develop a web-based expert system that facilitates early diagnosis of canine skin diseases. By enabling owners to identify potential issues independently, the system can offer guidance for initial care and encourage further action, such as consulting a veterinarian when necessary.

METHODS

Expert System Design

This expert system is designed to assist in the early diagnosis of canine skin diseases by applying the Dempster-Shafer method as a decision-making approach based on evidence. The system architecture is structured to facilitate the diagnosis process through two main environments: the development environment and the consultation environment. By integrating expert knowledge into a user-friendly mechanism, the system enables non-expert users to effectively access diagnostic information and recommendations.

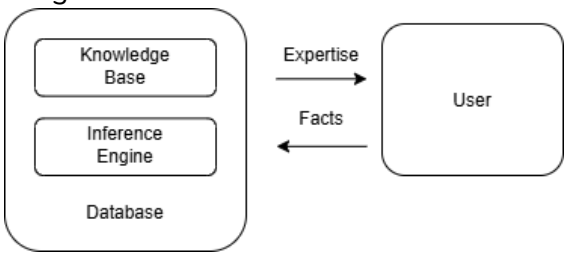

Figure 1. System Overview

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Figure 1 illustrates the framework of the expert system for diagnosing canine skin diseases, comprising two main components: the development environment and the consultation environment. The development environment is used to input expert knowledge into the system, while the consultation environment is accessible to non-expert users seeking information from the expert system. The expert system operates on a knowledge-based framework, functioning by receiving data or facts from users and responding with consultations or recommendations. Internally, the system consists of two key components: the knowledge base and the inference engine. The knowledge base stores the necessary information, while the inference engine processes this information to generate conclusions in response to user queries. The foundational concept of the expert system encompasses expertise, experts, knowledge transfer, rules, inference, and explanatory capabilities [9].

Research Flow

The flowchart of the expert system is designed to provide a comprehensive overview of the system's workflow in diagnosing canine skin diseases systematically and structurally.

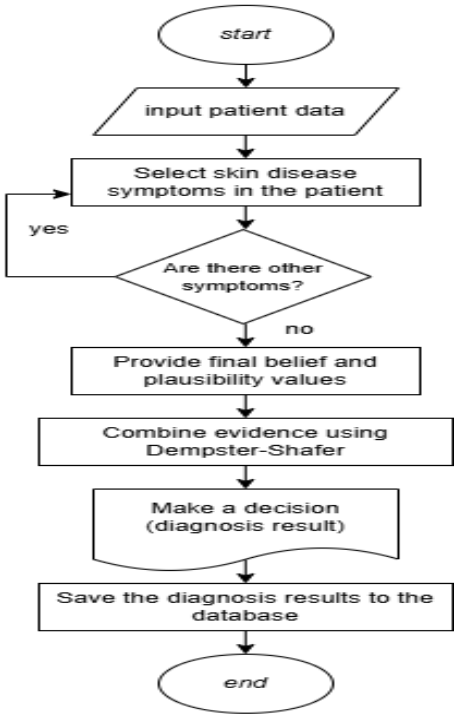

Figure 2. Research Flow

Figure 2 illustrates the flowchart design of this expert system, detailing the step-by-step process for conducting early diagnoses of canine skin diseases using a web-based platform. The process begins with the user inputting patient data, specifically information about the dog being diagnosed, into the system. The user is then prompted to select the symptoms exhibited by the dog. After entering one symptom, the system asks whether there are additional symptoms to input. If there are, the user is redirected to the previous step to add more symptoms. This process repeats until all observed symptoms have been recorded.

Once all symptoms are inputted, the system proceeds to the calculation phase using the Dempster-Shafer method. At this stage, the system assigns a belief value (ranging from 0 to

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1) to each symptom, representing the degree of confidence that the symptom is associated with a specific disease. It also calculates the plausibility value for each symptom. The evidence from all entered symptoms is then combined using Dempster-Shafer theory to determine the most probable diagnosis. The diagnostic result is subsequently stored in the database for future use, such as maintaining medical records or conducting further analysis. This completes the expert system's workflow, providing diagnostic results that can guide the appropriate treatment of canine skin diseases.

The Dempster-Shafer method

The Dempster-Shafer method, also known as the theory of belief functions, is an extension of Bayesian subjective probability theory. It allows the calculation of confidence levels based on the probability of related questions [10]. Introduced by Arthur P. Dempster and Glen Shafer, this method addresses uncertainty by using a range of probabilities instead of a single probability value[10]. The Dempster-Shafer theory combines evidence to generate confidence levels based on all available evidence.

In this method, experts assign belief values ranging from 0 to 1. These values are then used to calculate plausibility, which determines the likelihood of a diagnostic outcome [11]. Plausibility values are similarly calculated within the range of 0 to 1. One significant advantage of the Dempster-Shafer method is its ability to refine hypotheses as more evidence is gathered [12]. The evidence collected is associated with a broader range of hypotheses than initially considered. This approach integrates new facts to enhance diagnostic accuracy, making irrelevant reasoning less impactful [13].

The Dempster-Shafer method combines evidence through a process of belief-value aggregation. This aggregation is used to integrate the belief values from various pieces of evidence to produce a diagnosis with the highest confidence percentage. To address inconsistencies, the method uses intervals, represented as follows:

Belief (Bel)

Belief (Bel) indicates the strength of the evidence (symptoms) supporting a particular hypothesis. A Bel value of 0 signifies no evidence supporting the proposition, while a Bel value of 1 indicates absolute confidence [14] . The range of Bel values typically falls between 0 and 1.

Plausibility (Plausibility)

The plausibility value, calculated using the formula below, serves as the basis for determining the reasonableness of a hypothesis:

$$P1(\theta) = 1 - \text{Bel} \quad \text{..... (1)}$$

Dempster-Shafer Combination Rule

The Dempster-Shafer combination formula integrates multiple pieces of evidence to calculate the combined belief value:

$$m3(Z) = \frac{\sum_{X \cap Y = Z} m1(X).m2(Y)}{1 - \sum_{X \cap Y = \phi} m1(X).m2(Y)} \quad \text{..... (2)}$$

This method systematically combines evidence to produce a diagnostic result with the highest possible confidence, making it a powerful tool for managing uncertainty in decision-making.

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RESULTS AND DISCUSSION

Rule Base

Based on the knowledge acquired through literature review and interviews with experts, a rule table has been developed for the expert system in early diagnosis of skin diseases in dogs using the Dempster-Shafer method. The rule base serves as the core of the expert system, storing knowledge and rules to support decision-making or provide recommendations within the consultation process [15]. The knowledge gathered includes 12 types of diseases and 23 interrelated symptoms. This data is summarized in a rule table that serves as a guideline for the expert system to identify potential diseases based on the combination of symptoms experienced by the dog. These rules enable the expert system to provide an accurate preliminary diagnosis and support informed decision-making in disease management.

The rules in this expert system are represented in the form of IF-THEN production rules, which present a logical relationship between conditions and actions or conclusions. These production rules operate with the pattern: "IF a certain condition is met, THEN an action or conclusion will be produced." For example, if a dog exhibits symptoms such as G01 (itching), G02 (loss of appetite), G03 (lack of enthusiasm), G06 (lumps), G07 (reddened skin), G08 (certain skin areas appear darker), G10 (hair loss), G13 (hair appears with different color and structure), G14 (dry and rough skin), and G17 (baldness), the system will provide a possible diagnosis of Acral Lick Granuloma (P1). This rule allows for the analysis of complex symptom combinations to produce a more accurate data-driven diagnosis.

Rule	Production Rule (AND)
R1	IF G01 AND G02 AND G03 AND G06 AND G07 AND G08 AND G10 AND G13 AND G14 AND G17 THEN P1
R2	IF G01 AND G05 AND G07 AND G10 AND G14 AND G17 THEN P2
R3	IF G01 AND G06 AND G07 AND G10 AND G11 AND G12 AND G14 AND G17 AND G21 AND G22THEN P3
R4	IF G08 AND G10 AND G12 AND G13 AND G14 AND G16 AND G17 THEN P4
R5	IF G01 AND G02 AND G03 AND G04 AND G10 AND G14 AND G16 AND G17 THEN P5
R6	IF G01 AND G06 AND G07 AND G08 AND G09 AND G12 AND G16 AND G17 THEN P6
R7	IF G01 AND G07 AND G08 AND G09 AND G10 AND G12 AND G16 AND G17 AND G18 THEN P7
R8	IF G01 AND G02 AND G05 AND G07 AND G15 AND G16 AND G18 THEN P8
R9	IF G01 AND G02 AND G03 AND G07 AND G08 AND G10 AND G15 AND G16 AND G17 AND G18 THEN P9
R10	IF G01 AND G05 AND G06 AND G08 AND G09 AND G10 AND G12 AND G13 AND G14 THEN P10
R11	IF G01 AND G03 AND G19 AND G23 THEN P11
R12	IF G01 AND G07 AND G10 AND G16 AND G19 THEN P12

The next step is to establish the relationship between diseases and their symptoms, as well as to determine the weight values based on expert assessment. This rule data includes

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a total of 94 rules designed to systematically link symptom combinations with potential diseases. Weighting is done by assigning belief and plausibility values to each rule, using a scale from 0 to 1. These values reflect the expert's level of confidence in the relationship between a specific symptom and the associated disease. With the weights assigned to each rule, the expert system can process the combination of symptoms input by the user to produce a diagnosis with a measurable probability level. This weighting allows the system to handle uncertainty more effectively, while providing accurate and reliable diagnostic results. Table 2 contains a total of 94 rules that cover the relationship between skin diseases in dogs and their symptoms, along with the weight values that reflect the expert's level of confidence.

Table 2. Rule Data

Disease Code	Disease Name	Symptom	Belief
P01	Acral Lick Granuloma	Itching	0.8
		Loss of appetite (anorexia)	0.5
		Lack of enthusiasm (lethargy)	0.5
		Lump	0.7
		Reddened skin	0.8
		Darker skin areas (hyperpigmentation)	0.8
		Hair loss	0.8
		Hair with slightly different structure	0.7
		Dry and rough or dull skin	0.7
		Bald spots	0.8
P02	Acute Moist Dermatitis	Itching	0.7
		Thickened skin	0.7
		Reddened skin	0.8
		Hair loss	0.8
		Dry and rough or dull skin	0.6
		Bald spots	0.7
P03	Atopic Dermatitis	Itching	0.9
		Lump	0.6
		Reddened skin	0.8
		Hair loss	0.9
		Sneezing	0.7
		Nasal discharge	0.7
		Watery eyes	0.7
		Rough patches on skin	0.8
		Dry and rough or dull skin	0.9
		Bald spots	0.8
P04	Follicular Dysplasia	Darker skin areas (hyperpigmentation)	0.9
		Hair loss	0.9
		Rough patches on skin	0.7
		Hair with slightly different structure	0.8
		Dry and rough or dull skin	0.8
		Scaly skin	0.8
		Bald spots	0.9

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Disease Code	Disease Name	Symptom	Belief
P05	Malassezia Dermatitis	Itching	0.9
		Loss of appetite (anorexia)	0.6
		Lack of enthusiasm (lethargy)	0.7
		Lump	0.8
		Hair loss	0.8
		Dry and rough or dull skin	0.8
		Scaly skin	0.8
		Bald spots	0.8
P06	Sarcoptic Mange	Itching	0.9
		Lump	0.6
		Reddened skin	0.9
		Darker skin areas (hyperpigmentation)	0.9
		Hair loss	0.9
		Rough patches on skin	0.9
		Scaly skin	0.9
		Bald spots	0.9
		Skin with pus	0.8
P07	Dermatophytosis	Itching	0.9
		Reddened skin	0.8
		Skin with pus	0.7
		Hair loss	0.7
		Rough patches on skin	0.8
		Scaly skin	0.8
		Bald spots	0.8
		Facial wounds	0.8
		Darker skin areas (hyperpigmentation)	0.8
P08	Pemphigus foliaceus	Itching	0.9
		Loss of appetite (anorexia)	0.7
		Thickened skin	0.8
		Reddened skin	0.8
		Nasal wounds	0.8
		Scaly skin	0.8
		Facial wounds	0.8
P09	Demodicosis	Itching	0.8
		Loss of appetite (anorexia)	0.8
		Lack of enthusiasm (lethargy)	0.8
		Reddened skin	0.8
		Darker skin areas (hyperpigmentation)	0.8
		Hair loss	0.9
		Nasal wounds	0.7
		Scaly skin	0.9
		Bald spots	0.9
		Facial wounds	0.9

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Disease Code	Disease Name	Symptom	Belief
P10	Pediculosis	Itching	0.8
		Thickened skin	0.7
		Lump	0.7
		Darker skin areas (hyperpigmentation)	0.7
		Skin with pus	0.7
		Hair loss	0.8
		Rough patches on skin	0.6
		Hair with slightly different structure	0.6
		Dry and rough or dull skin	0.7
P11	Impetigo	Pustular bumps	0.8
		Itching	0.8
		Lack of enthusiasm (lethargy)	0.6
		Diarrhea	0.5
P12	Canine Pyoderma	Painful itching	0.8
		Hair loss	0.8
		Scaly skin	0.8
		Pustular bumps	0.9
		Reddened skin	0.9

The next step is to build an inference engine to perform symptom tracing. This process is carried out after all disease-symptom pairs have been compiled and weighted, as shown in Table 10. The symptom tracing uses the Dempster-Shafer method, where the established rules are applied to analyze each symptom input by the user. Then, belief and plausibility values are calculated and combined to produce a diagnosis with a measurable probability level.

Implementation

This expert system for early diagnosis of skin diseases in dogs uses the Dempster-Shafer method as a calculation model to determine the final diagnosis result along with its percentage value. In the first stage, the symptoms selected by the user are input and processed using the Dempster-Shafer method. The process begins by inputting the symptoms selected by the user into the system, which are then matched with the rules in the knowledge base.

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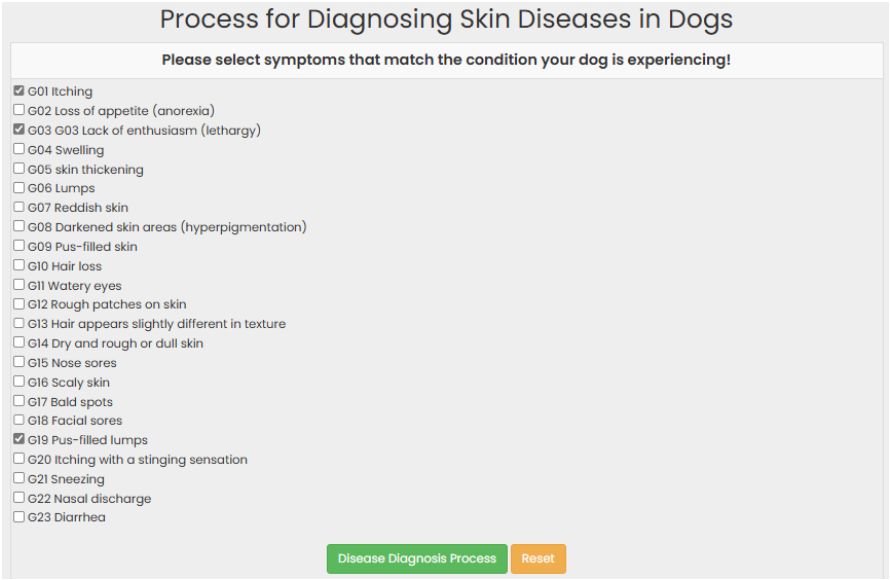

Figure 3. Interface for Selecting Symptoms in Dog Skin Disease Diagnosis System

To illustrate the calculation algorithm of the Dempster-Shafer method, we can perform a manual calculation simulation using the Dempster-Shafer formula. As an example, the following is the Dempster-Shafer calculation to diagnose a disease in a dog exhibiting the symptoms of Itching (G01), Lack of enthusiasm (lethargy) (G03), and Pus-filled lumps (G19). The following calculation steps show some values for the belief function (m):

The symptom Itching m1(G01) has a weight value of 0.9. This symptom (G01) is found in diseases with the following codes: (P01, P02, P03, P05, P06, P07, P08, P09, P10, P11). Therefore:

m1 {P01, P02, P03, P05,P06,P07,P08,P09,P10,P11}

m1(G01)belief= 0.8

m1(θ) = 1 – 0.8 = 0.2 (nilai plausibility)

The symptom Lack of enthusiasm (lethargy), m2(G03), has a weight value of 0.7. This symptom (G03) is found in diseases with the following codes: (P01, P05, P09, P11). Therefore:

m2 { P01,P05, P09,P11}

m2(G03)belief= 0.5

m2(θ) = 1 – 0.5 = 0.5 (nilai plausibility)

The result of this stage is the initial density value for each disease based on the selected symptoms. This initial density value becomes the main input in the inference process using the Dempster-Shafer method, which will combine evidence from multiple symptoms to produce a diagnosis with a certain level of confidence. After the initial density values are calculated, the program code proceeds to the process of combining new density values using the combination calculation rules in the Dempster-Shafer method. This process includes calculating the belief values for each possible disease based on the combination of selected symptoms. The system uses the Frame of Discernment (FOD) to ensure that all possible diseases are considered, including the uncertainty represented by the symbol "θ." This stage

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aims to combine all the evidence from the existing symptoms, update the beliefs, and reduce uncertainty. The new density values obtained are sorted based on the highest confidence levels, and the final results are displayed in the form of a diagnosis. This diagnosis lists the disease with the highest confidence value, along with the belief percentage as the system's accuracy level. The execution result of this code will display the following view:

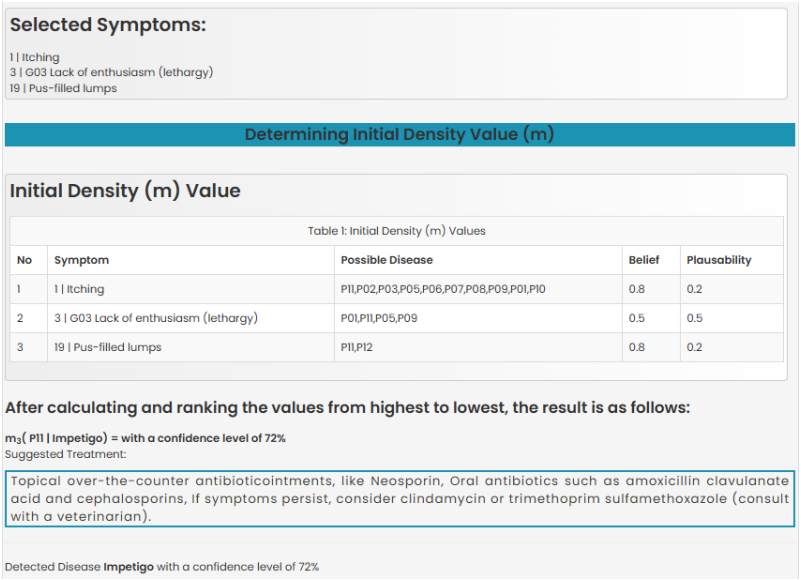

Figure 4. Interface for Diagnosis Result and Suggested Treatment for Dog Skin Diseases

In Figure 5, the system shows the diagnostic process with the symptoms selected by the user, namely G01 (Itching), G03 (Lack of enthusiasm (lethargy)), and G19 (Pus-filled lumps). The process results in a final diagnosis of Impetigo with a confidence level of 72%. Additionally, the system also provides relevant treatment recommendations, such as the use of topical over-the-counter antibiotic ointments like Neosporin, oral antibiotics such as amoxicillin clavulanate acid and cephalosporins, and if symptoms persist, consider clindamycin or trimethoprim sulfamethoxazole (consult with a veterinarian). This output indicates that the expert system has successfully integrated probabilistic methods to support the diagnostic process.

Below is an example of the manual calculation of the three symptoms input by the user, using the Dempster-Shafer combination rules. The Dempster-Shafer combination is performed by cross-multiplying the belief values of each symptom.

	m2 {P01,P05, P09,P11} 0.5	m2 {θ} 0.5
m1 {P01, P02, P03, P05,P06,P07,P08,P09,P10,P11} 0.8	P01, P05, P09, P11 0.4	P01, P02, P03, P05,P06,P07,P08,P09,P10 ,P11 0.4
m {θ} 0.2	P01, P05, P09, P11 0.1	Θ 0.1

$$m3(P01, P05, P09, P11) = \frac{(0.8x0.5) + (0.2x0.5)}{1 - 0}$$

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$$m3(P01, P05, P09, P11) = \frac{0.4 + 0.1}{1 - 0} = 0.5$$

$$m3(P01, P02, P03, P05, P06, P07, P08, P09, P10, P11) = \frac{(0.8 \text{ x } 0.5)}{1 - 0} = 0.4$$

$$m3(\theta) = \frac{0{,}1}{1 - 0} = 0{,}1$$

After the m3 values are determined, these values are recalculated by considering a new symptom, which is Pus-filled lumps (G19). The symptom Pus-filled lumps (G19) has a weight value of 0.8. This symptom is found in diseases with the codes P11 and P12.

Therefore:

m4 { P11, P12 }
m4(G19)bel = 0.8
m4(θ) = 1 – 0.8 = 0.2

	m4 { P11, P12 } 0.8	m4 {θ} 0.2
m3 {P01, P05, P09, P11} 0.5	P11 0.4	P01, P05, P09, P11 0.1
m3 {P01, P02, P03, P05,P06,P07,P08,P09,P10,P11} 0.4	P11 0.32	P01, P02, P03, P05,P06,P07,P08,P09,P10,P11 0.08
m3 {θ} 0.1	P11, P12 0.08	θ 0.02

$$m5\ (P11) = \frac{(0.5 \text{ x } 0.8) + (0.4 \text{ x } 0.8)}{1 - 0}$$

$$m5\ (P11) = \frac{0.4 + 0.32}{1 - 0} = 0{,}72$$

$$m5\ (P11, P12) = \frac{(0.8 \text{ x } 0.1)}{1-0} = 0{,}08$$

$$m5\ (P01, P05, P09, P11) = \frac{(0.5 \text{ x } 0.2)}{1 - 0} = 0.1$$

$$m5\ (P01, P02, P03, P05, P06, P07, P08, P09, P10, P11) = \frac{(0.2 \text{ x } 0.4)}{1 - 0} = 0{,}08$$

$$m5\ \theta = \frac{(0.2 \text{ x } 0.1)}{1 - 0} = 0{,}02$$

At the final stage of the calculation, m5 shows that for the diagnosis of P11 (impetigo), the certainty level is 0.72 or 72%. This 72% value is derived from the m5 calculation for the diagnosis of P11, which indicates the highest level of certainty in diagnosing skin diseases in dogs based on the symptoms that have been identified. This value is obtained from the combination of belief mass and previous calculations, where m5(P11) reaches 0.72, which is then converted into a percentage using the formula 0.72 x 100% = 72%. Thus, this result provides a clear picture of the possible skin disease the dog is experiencing. Based on the identified symptoms, impetigo has a 72% likelihood of being the most probable diagnosis.

User Acceptance Test (UAT)

After the implementation of the inference engine is completed, the next step is to test the expert system using the User Acceptance Test (UAT). This test aims to evaluate the user's acceptance level of the system. Users are asked to use the expert system to diagnose their

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dog's skin disease and fill out a questionnaire via Google Form consisting of 10 questions. The questionnaire is designed to assess aspects such as ease of use, clarity of information, system performance, and the quality of the solution provided, with ratings on a scale from 1 to 4 (Strongly Disagree to Strongly Agree). The results of the UAT show that the majority of respondents provided positive feedback, with most responses falling under the categories Agree (A) and Strongly Agree (SA). The average percentage of all questions reached 89.091%, which is categorized as "Excellent." This indicates that the website-based expert system is effective, aligns with the development goals, and is well-accepted by users as a tool for early diagnosis of skin diseases in dogs.

$$\text{Question Percentage} = \frac{\text{total score}}{\text{total weight}} x\ 100\%$$

Tabel 3. Hasil Olah Data Pengujian User Acceptance Test (UAT)

No	Question	Assessment				Total	Percentage Score
		(SA)	(A)	(D)	(SD)		
1	Is the user interface (UI) of the expert system easy to understand and use when conducting an initial diagnosis of dog skin diseases?	56	21	2		79	89.77%
2	Is the information displayed regarding diagnostic results and treatment solutions clear and helpful in understanding the condition and necessary treatment steps?	36	39			75	85.23%
3	Does the input validation (e.g., phone number, age, weight, dog breed, owner's name, and dog's gender) in the "enter your and your dog's personal data" feature work well and provide clear error messages for incorrect data?	52	27			79	89.77%
4	Does the system provide practical solutions for initial diagnosis relevant to the symptoms you input as a user?	44	33			77	87.50%
5	How quickly does the system process symptom data and display diagnostic results? Are there any disruptive delays? If there are no delays and the system processes data quickly, select 'Strongly Agree.' If you experience disruptive delays, choose the option that	64	18			82	93.18%

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No	Question	Assessment				Total	Percentage Score
		(SA)	(A)	(D)	(SD)		
	matches your level of dissatisfaction.						
6	Does using this expert system help you take preventive measures earlier for skin diseases in your dog?	56	24			80	90.91%
7	Are the features in this expert system easily accessible and clearly understood?	48	30			78	88.64%
8	Is the form feature for entering owner and dog personal data easy to fill out and understand for you (the user)?	44	33			77	87.50%
9	Does this system have a responsive design and is it easy to use on mobile devices (smartphones or tablets)?	48	30			78	88.64%
10	Does this expert system provide relevant and easy-to-implement care solutions or recommendations based on the diagnostic results?	56	21	2		79	89.77%

From the data processing results in Table 3, the User Acceptance Test (UAT) results will be averaged to obtain the final score of the User Acceptance Test (UAT). This final score will serve as the overall result of the User Acceptance Test (UAT), which is calculated using the following formula and calculations.

$$\text{Average Score} = \frac{\text{total percentage scores}}{\text{number of questions}}$$

$$\text{Average Score} = \frac{(89.77\% + 85.23\% + 89.77\% + 87.50\% + 93.18\% + 90.91\% + 88.64\% + 87.50\% + 88.64\% + 89.77\%)}{10}$$

$$\text{Average Score} = \frac{890.9063636\ \%}{10}$$

$$\text{Average Score} = 89.091\ \%$$

From the calculations performed, it can be concluded that the website-based expert system for early diagnosis of skin diseases in dogs has met the development goals and received positive feedback from 22 respondents. With an average score of 89.091%, which indicates that the system is rated very positively by dog owners, the system is considered effective and accurate in helping users diagnose skin diseases in dogs early, based on a website platform.

Accuracy Testing

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The accuracy testing of the expert system was conducted in collaboration with an animal health expert to assess the system's performance in diagnosing skin diseases in dogs using the Dempster-Shafer approach, which handles uncertainty in decision-making. A total of 22 diagnosis cases from the respondents were tested and compared with the diagnoses provided by the expert. The results of this comparison are presented in Table 4, which is used to assess the accuracy level of the developed expert system, ensuring that the diagnoses produced align with professional standards.

Table 4. Accuracy Testing Results

Diagnosis No.	Selected Symptoms	Expert System Diagnosis	Expert Diagnosis	Diagnosis Match
1	Itching (G01), Skin Thickening (G05), Reddish Skin (G07), Baldness (G17), Sneezing (G21)	Atopic Dermatitis (41,18 %), Acute Moist Dermatitis (37,06 %)	Atopic Dermatitis	Valid
2	Itching (G01), Skin Thickening (G05), Reddish Skin (G07), Hair Loss (G10), Baldness (G17)	Acute Moist Dermatitis (66,08 %)	Acute Moist Dermatitis	Valid
3	Itching (G01), Lumps (G06), Reddish Skin (G07), Hyperpigmentation (G08), Dry and Rough/Dull Skin (G14), Baldness (G17)	Acral Lick Granuloma (53,4%)	Acral Lick Granuloma	Valid
4	Itching (G01), Lumps (G06), Reddish Skin (G07), Hyperpigmentation (G08), Hair Loss (G10), Rough Skin Patches (G12), Scaly Skin (G16), Baldness (G17)	Sarcoptic Mange (64.6%)	Sarcoptic Mange	Valid
5	Itching (G01), Loss of Appetite (Anorexia) (G02), Skin Thickening (G05), Reddish Skin (G07), Nose Lesions (G15), Scaly Skin (G16)	Pemphigus Foliaceus (69,16%)	Pemphigus Foliaceus	Valid
6	Itching (G01), Reddish Skin (G07), Hair Loss (G10), Dry and Rough/Dull Skin (G14), Baldness (G17), Sneezing (G21)	Atopic Dermatitis (70%)	Atopic Dermatitis	Valid
7	Itching (G01), Lack of Enthusiasm (G03), Reddish Skin (G07), Hyperpigmentation (G08), Hair Loss (G10), Scaly Skin (G16), Pus-filled Lumps (G19)	Demodicosis (42,68%), Impetigo (0,87%), Canine Pyoderma (4,5%)	Demodicosis	Valid
8	Itching (G01), Lumps (G06), Hyperpigmentation (G08), Hair Loss (G10), Rough Skin Patches (G12), Scaly Skin (G16), Baldness (G17)	Sarcoptic Mange (54,05%)	Sarcoptic Mange	Valid

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Diagnosis No.	Selected Symptoms	Expert System Diagnosis	Expert Diagnosis	Diagnosis Match
9	Itching (G01), Loss of Appetite (Anorexia) (G02), Skin Thickening (G05), Reddish Skin (G07), Scaly Skin (G16)	Pemphigus Foliaceus (64,4%)	Pemphigus Foliaceus	Valid
10	Itching (G01), Lumps (G06), Reddish Skin (G07), Hyperpigmentation (G08), Scaly Skin (G16), Baldness (G17)	Sarcoptic Mange (48%)	Sarcoptic Mange	Valid
11	Itching (G01), Lumps (G06), Reddish Skin (G07), Hair Loss (G10), Baldness (G17), Sneezing (G21)	Atopic Dermatitis (70%)	Atopic Dermatitis	Valid
12	Itching (G01), Skin Thickening (G05), Lumps (G06), Dry and Rough/Dull Skin (G14), Scaly Skin (G16))	Malassezia Dermatitis (13,58%), Sarcoptic Mange (9,91%), Pemphigus Foliaceus (9,91%), Pediculosis (28,89%)	Sarcoptic Mange	Invalid
13	Itching (G01), Lumps (G06), Reddish Skin (G07), Hyperpigmentation (G08), Hair Loss (G10), Rough Skin Patches (G12)	Sarcoptic Mange (35,84%)	Sarcoptic Mange	Valid
14	Itching (G01), Loss of Appetite (Anorexia) (G02), Lumps (G06), Reddish Skin (G07), Hair Loss (G10), Baldness (G17)	Acral Lick Granuloma (30%)	Acral Lick Granuloma	Valid
15	Itching (G01), Skin Thickening (G05), Baldness (G17)	Acute Moist Dermatitis (56%)	Acute Moist Dermatitis	Valid
16	Itching (G01), Skin Thickening (G05), Reddish Skin (G07), Hyperpigmentation (G08), Rough Skin Patches (G12), Altered Hair Structure (G13), Sneezing (G21)	Acral Lick Granuloma (8.37%) Atopic Dermatitis (10.86%) Pediculosis (53.88%)	Atopic Dermatitis	Invalid
17	Itching (G01), Hair Loss (G10), Diarrhea (G23)	Impetigo (16.67%)	Impetigo	Valid
18	Itching (G01), Loss of Appetite (Anorexia) (G02), Lack of Enthusiasm (G03), Hyperpigmentation (G08), Facial Lesions (G18), Scaly Skin (G16)	Demodicosis (46.4%)	Demodicosis	Valid
19	Itching (G01), Lumps (G06), Reddish Skin (G07), Hair Loss (G10)	Atopic Dermatitis (50%)	Atopic Dermatitis	Valid
20	Itching (G01), Loss of Appetite (G02), Hair Loss (G10), Watery Eyes (G11), Baldness (G17)	Atopic Dermatitis (41.18%)	Atopic Dermatitis	Valid

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Diagnosis No.	Selected Symptoms	Expert System Diagnosis	Expert Diagnosis	Diagnosis Match
21	Itching (G01), Skin Thickening (G05), Lumps (G06), Hair Loss (G10), Dry and Rough/Dull Skin (G14)	Pediculosis (56%)	Pediculosis	Valid
22	Itching (G01), Loss of Appetite (Anorexia), Watery Eyes (G11), Rough Skin Patches (G12), Altered Hair Structure (G13)	Acral Lick Granuloma (19.31%) Atopic Dermatitis (24.14%) Pediculosis (26.48%)	Atopic Dermatitis	Invalid

After system testing and comparison with expert diagnoses, out of the 22 diagnosis results tested, 19 were accurate according to the expert, while 3 were inaccurate. The inaccuracies were caused by the system's use of the highest percentage parameter, which does not always precisely reflect the expert's diagnosis. The system's accuracy level is calculated to assess how well the expert system is able to diagnose skin diseases in dogs in accordance with professional standards. This accuracy calculation is crucial to ensure the reliability of the system, where a high accuracy level indicates the effectiveness and trust of users in the diagnoses provided by the expert system.

$$\text{Accuracy Value} = \frac{\text{total correct data}}{\text{total data}} x\ 100\%$$

$$\text{Accuracy Value} = \frac{19}{22} x\ 100\%$$

Accuracy Value = 86,36 %

Based on testing conducted on 22 case samples, the expert system for early diagnosis of skin diseases in dogs using the Dempster-Shafer method achieved an accuracy level of 86.36%. This accuracy level indicates that the expert system is capable of providing diagnoses that closely match the results from animal experts, thus effectively supporting the diagnosis of skin diseases in dogs. With an accuracy of 86.36%, the system is considered highly accurate and has the potential to make a significant contribution in helping pet owners diagnose skin diseases in dogs early.

CONCLUSION

This study successfully developed a website-based expert system for the early diagnosis of skin diseases in dogs using the Dempster-Shafer method. The system addresses the issue of skin diseases in dogs in Bali and the lack of knowledge among dog owners by gathering data from experts and literature studies, resulting in a knowledge base consisting of 12 types of diseases and 23 symptoms. The implementation of the Dempster-Shafer method allows the system to handle uncertainty in decision-making, achieving a diagnosis accuracy level of 86.36%. The system was developed using PHP, JavaScript, PhpMyAdmin, Bootstrap, and Tailwind CSS, ensuring a responsive and user-friendly interface. The results of the User Acceptance Test (UAT) showed a user satisfaction level of 89.091%, indicating that the system is effective, accurate, and user-friendly. Therefore, this expert system can be relied

upon to assist in the early diagnosis of skin diseases in dogs, particularly for dog owners in Bali Province.

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