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E-Goat Doctor: An Expert System for the Diagnosis of Common Goat Diseases

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Abstract
The E-Goat Doctor is an expert system designed to diagnose common goat diseases, particularly in rural areas where access to veterinary services is limited. Utilizing a rule-based algorithm, the system analyzes symptoms provided by users and matches them with known diseases, offering accurate and timely diagnoses. The development of the E-Goat Doctor involved series of consultations with domain experts, ensuring a comprehensive knowledge base that addresses prevalent goat health issues in Northern Mindanao, Philippines, such as mastitis, foot rot, pneumonia, worm infestations, Enterotoxemia, and Calcium Deficiency. During testing, the system demonstrated high accuracy in diagnosing diseases, making it a valuable tool for goat farmers. The E-Goat Doctor not only improves the efficiency of disease management but also contributes to the overall health and productivity of goat herds. This expert system is positioned to be a significant asset in supporting sustainable goat farming practices, especially in regions with limited veterinary support.

Key Words: expert systems; inference engine; knowledge-based; goat diseases

1. Introduction

In recent years, Expert Systems (ES) have emerged as a powerful branch of artificial intelligence designed to emulate the decision-making abilities of a human expert (Mohan et al., 2019). These systems use knowledge and inference procedures to solve complex problems that would normally require human expertise. By leveraging databases of expert knowledge, ES can provide diagnoses, offer recommendations, and facilitate decision-making processes in various fields (Saibene et al., 2021). This capability makes ES important in areas where expert knowledge is critical but not always readily available.

The evolution of ES has significantly impacted disease diagnosis across various domains, including human, animal, and plant health. These systems, rooted in artificial intelligence, replicate expert knowledge to aid in diagnosing diseases, thereby enhancing both accessibility and efficiency (Anjara and Jaharadak, 2019). Numerous organizations and companies have integrated expert systems into their operations to enhance efficiency and accuracy. In healthcare, ES are used for diagnosing diseases, recommending treatments, and managing patient care. In finance, they assist with fraud detection and investment strategies. Agriculture has also benefited from ES through applications like crop management, pest control, and livestock health monitoring. In the context of goat farming, expert systems are used for a variety of applications, including disease diagnosis, nutrition management, and breeding optimization. ES help farmers make informed decisions that improve the health and productivity of their livestock.

For the development of the E-Goat Doctor, a rule-based algorithm was employed. Rule-based systems operate on a set of "if-then" rules derived from expert knowledge, allowing for systematic diagnosis and problem-solving (Purnomo et al., 2020). This approach has been successfully implemented in various countries, including the Philippines, where it aids in sectors ranging from medical diagnosis to agricultural management.

The rule-based algorithm's flexibility and precision make it a suitable choice for building an expert system capable of accurately diagnosing common goat diseases.

The Philippine rural economy depends heavily on goats, and they have the potential to reduce poverty. It's critical to provide food security and jobs in rural areas. Intong et al. (2018) state that increasing farmers' ability to produce livestock is essential for raising productivity, which is particularly significant in areas such as the Northern Philippines. The motivation behind creating the E-Goat Doctor stems from the need to support farmers in diagnosing and managing goat diseases more effectively. In many regions in the Philippines, especially rural areas like Ramain, Sultan Naga Dimaporo, access to veterinary services is limited. This gap in service can lead to the mismanagement of diseases, resulting in significant economic losses and poor animal welfare. By providing a reliable and accessible diagnostic tool, the E-Goat Doctor aims to empower farmers with the knowledge and guidance needed to maintain the health of their herds, ultimately contributing to improved productivity and sustainability in goat farming.

2. Literature Review

The application of expert systems in the livestock industry has seen significant advancements in recent years. This review explores various studies to highlight the developments and applications of expert systems in diagnosing and managing animal diseases.

Lee et al. (2023) underscore the growing role of expert systems (ES) in diagnosing and managing animal diseases, setting the stage for understanding the broader impact of ES in the livestock industry. Similarly, Yonas Tesfaye Burik (2019) focused on creating a rule-based knowledge-based system for diagnosing and treating goat diseases in Ethiopia, highlighting the potential of ES to address challenges faced by farmers, especially in areas with limited access to veterinary services and expert knowledge. Likewise, Pratama et al. (2018) developed an expert system for diagnosing vertebrate animals using Visual Prolog 8.0, based on if-then rules and a forward chaining inference mechanism, addressing the challenge of identifying vertebrate animals that migrate or move long distances.

Moreover, Elsayed and Hazman (2021) developed a mobile-based expert system for diagnosing and treating poultry diseases, designed to function offline to assist farmers in areas without internet connectivity, ensuring continuous support in remote regions. In addition, Abishaik Mohan, R. Deepak Raju, and Dr. P. Janarthanan (2019) proposed the Animal Disease Diagnosis Expert System (ADDES) using Convolutional Neural Networks (CNN), emphasizing the importance of dynamically segmenting and extracting features from diseased images to produce accurate diagnostic results. Furthermore, Anjara and Jaharadak (2019) presented a hybrid model that integrates machine learning algorithms with expert systems, combining data from various sources, including sensor data and veterinary inputs, to enhance diagnostic accuracy in livestock.

Additionally, Primova, Mukhamedieva, and Safarova (2022) explored the application of fuzzy rule-based algorithms in diagnosing animal diseases, highlighting the effectiveness of fuzzy rules in enhancing diagnostic accuracy by accommodating the inherent uncertainties and complexities in disease detection. Safarova (2021) further investigates the use of fuzzy logic in diagnosing non-communicable diseases in high-yielding dairy cows, such as ketosis and osteodystrophy, demonstrating a novel approach to predict and classify these diseases using fuzzy set membership functions based on clinical, morphochemical, and rumen content factors.

Moreover, Zhang and Chen (2020) developed an advanced automatic detection system for sick chickens using an improved Residual Network (ResNet), integrating IoT and big data technologies to monitor and analyze poultry health and performance, focusing on broilers as a case study. Additionally, Alkan and Akyüz (2024) investigated the advantages of using expert systems to project dairy cattle farms, specifically focusing on a case study in Menemen, Turkey. Their research, conducted at Ege University, demonstrates how expert systems can enhance the management and projection of dairy cattle farms, providing valuable insights and recommendations for optimizing farm operations and productivity.

Furthermore, Mustafidah, Amin, and Fatimah (2018) developed an expert system for determining the type of cats and how to care for them, utilizing a forward chaining method to diagnose cat breeds based on specific characteristics and provide guidance on proper care tailored to the identified breed. This study showcases the versatility of expert systems in addressing a wide range of animal-related concerns, extending beyond livestock to companion animals as well.

The reviewed literature demonstrates the significant advancements and diverse applications of expert systems in diagnosing and managing animal diseases. From rule-based systems and mobile applications to advanced computational techniques and fuzzy logic, expert systems are proving to be invaluable tools in the livestock industry and beyond.

3. Methodology

This section describes the methodology employed in developing the E-Goat Doctor Expert System.

The Expert System

In this study, the researcher adapted the typical system architecture of an Expert System as described by Elsayed and Hazman (2021), Burik (2019), and Mohan et al. (2019). The architecture involves the following components:

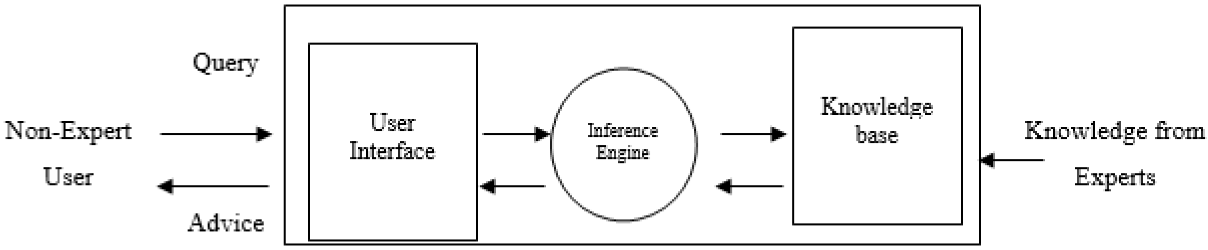

Fig. 1. Expert System Architecture

Figure 1 illustrates the E-Goat Doctor expert system's architecture. Non-expert users input queries about goat health, which are processed using expert knowledge stored in the system. This knowledge, gathered from domain experts, is utilized by the inference engine to provide accurate advice and diagnoses. The user interface facilitates the input of queries and the delivery of expert advice, ensuring that users receive accurate and comprehensible guidance on managing common goat diseases.

The methodology for this study followed the structured approach of the Software Development Life Cycle (SDLC), ensuring a systematic and organized development process.

3.1. Requirements Gathering

The requirements gathering stage involved interviews with domain experts to collect critical information for the expert system. The researcher conducted interviews with Ms. Chelame Navas, a Master of Science in Animal Science with expertise in goat health. Additionally, a veterinary expert from a local municipality provided valuable insights into common goat diseases, symptoms, and diagnostic procedures. This collective expertise formed the foundation of the knowledge base for the E-Goat Doctor, ensuring the system's relevance and accuracy in diagnosing goat health issues.

3.2. Analysis and Design

This phase involves analyzing the gathered requirements and designing the system to meet those requirements.

3.2.1 Legend. In this section, we define the symbols and abbreviations used throughout the E-Goat Doctor expert system. The legend serves as a reference to ensure consistency and clarity in the representation of diseases and symptoms within the knowledge base. Each common goat disease and its associated symptoms are assigned unique codes for ease of identification and processing within the system.

Table 1. Legend on E-Goat Doctor Expert System

Common Goat Diseases	Code	Symptoms	Code	Common Goat Diseases	Code	Symptoms	Code
Mastitis	Ma	Swollen Under	SU	**Enterotoxemia**	Ent	Abdominal Pain	AP
		Reduced Milk Yield	RMY			Bloat	Bl
		Fever (39.1˚Cup)	Fe			Lethargy	Le
		Pain	Pa			Fever	Fe
		Milk discoloration	MD			Visible Blood	VB
		Foul Odor	FO			Water Feces	WF
		Pus	Pus			Panting	P
Foot Rot	FR	Foul Odor	FO	Calcium Deficiency	CD	Lameness	La
		Swelling	Sw			Rickets	Ri
		Pus	Pus			Fever	Fe
Pneumonia	Pne	Coughing	Co				
		Nasal Discharge	ND				
		Fever (39.1˚Cup)	Fe				
		Difficulty Breathing 15.1beat/min up	DB				
Worm Infestation	WI	Weight Loss	WL				
		Loss of Appetite	La				
		Watery Diarrhea	Di				
		Anemia	An				
		Poor Hair Coat	PHC				
		Ascites	A				
		Bottle Jaw	BJ				

3.2.2 Knowledge Tree. Knowledge tree is a common method that can be used in the simulation of performance in a computer program (Sultan et al., 2020). The knowledge tree represents the hierarchical structure of the knowledge base within the E-Goat Doctor expert system. It organizes the expert knowledge into a logical framework, enabling efficient navigation and retrieval of information. The tree structure begins with broad categories of goat diseases. Each category branches out into specific diseases, and further into symptoms associated with each disease. This hierarchical organization facilitates the systematic diagnosis by guiding the inference engine through relevant pathways to arrive at accurate conclusions based on user inputs.

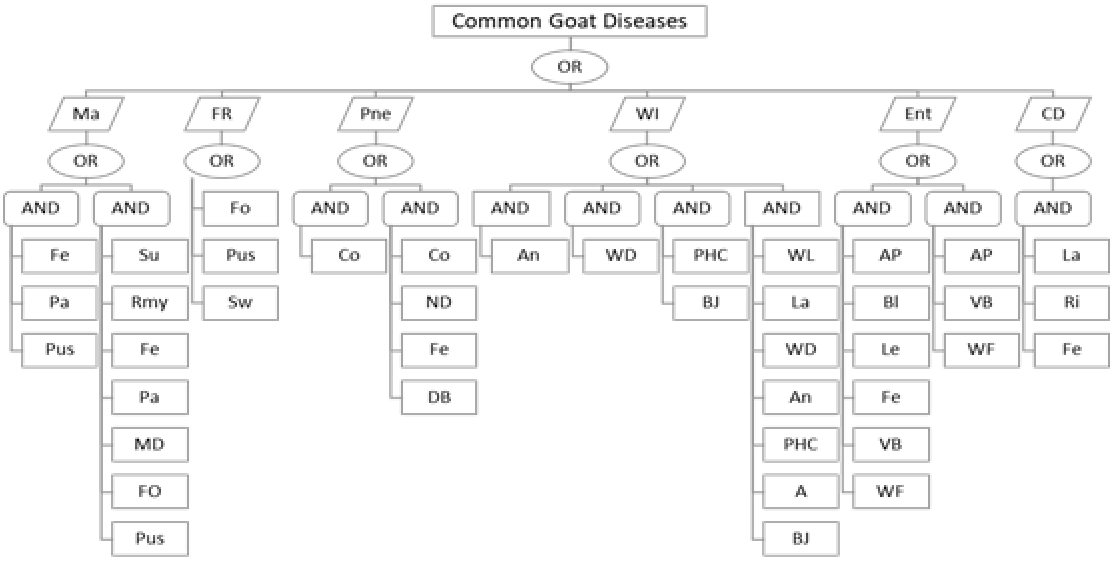

Fig. 2. Knowledge Tree on E-Goat Doctor Expert System

3.2.3 Predicates. This section describes the specific observations or symptoms associated with common goat diseases. These predicates are statements that will be used in the E-Goat Doctor expert system to identify and diagnose goat diseases based on the symptoms observed. Each predicate links a symptom to a disease, allowing the system to make logical conclusions about the potential illness affecting a goat.

Table 2. Predicates on E-Goat Doctor Expert System

Predicates on Common Goat Diseases	
Mastitis	The Goat is experiencing Swollen Under
	The Goat is experiencing Reduced Milk Yield
	The Goat is experiencing Fever (39.1˚Cup)
	The Goat is experiencing Pain
	The Goat is experiencing Milk discoloration
	The Goat is experiencing Foul Odor
	The Goat is experiencing Pus
Foot Rot	The Goat is experiencing Foul Odor
	The Goat is experiencing Swelling
	The Goat is experiencing Pus
Pneumonia	The Goat is Coughing
	The Goat is experiencing Nasal Discharge
	The Goat is experiencing Fever (39.1˚Cup)
	The Goat is experiencing Difficulty in Breathing 15.1beat/min up

Worm Infestation	The Goat is experiencing Weight Loss
	The Goat is experiencing Loss of Appetite
	The Goat is experiencing Watery Diarrhea
	The Goat is experiencing Anemia
	The Goat is experiencing Poor Hair Coat
	The Goat is experiencing Ascites
	The Goat is experiencing Bottle Jaw
Enterotoxemia	The Goat is experiencing Abdominal Pain
	The Goat is experiencing Bloat
	The Goat is experiencing Lethargy
	The Goat is experiencing Fever
	The Goat is experiencing Visible Blood
	The Goat is experiencing Water Feces
	The Goat is Panting
Calcium Deficiency	The Goat is experiencing Lameness
	The Goat is experiencing Rickets
	The Goat is experiencing Fever (39.1˚Cup)

3.2.4 Rules. This section defines the relationships between symptoms and specific goat diseases. These rules are structured in an if-then format, where the presence of certain symptoms leads to the diagnosis of a particular disease. This logical framework allows the system to systematically evaluate the input symptoms provided by the user and determine the most likely disease affecting the goat.

Table 3. Rules on E-Goat Doctor Expert System

Rules on Common Goat Diseases	
RULE 1:	Ma => Fe **AND** Pa **AND** Pus
RULE 2:	Ma => Su **AND** Rmy **AND** Fe **AND** Pa **AND** MD **AND** FO **AND** Pus
RULE 3:	FR => FO **AND** Sw **AND** Pus
RULE 4:	Pne => Co
RULE 5:	Pne => Co **AND** ND **AND** Fe **AND** DB
RULE 6:	WI => An
RULE 7:	WI => WD
RULE 8:	WI => PHC **AND** BJ
RULE 9:	WI => WL **AND** La **AND** WD **AND** an **AND** PHC **AND** A **AND** BJ

RULE 10:	Ent => AP **AND** VB **AND** WF
RULE 11:	Ent => AP **AND** BI **AND** Le **AND** Fe **AND** VB **AND** WF
RULE 12:	CD => La **AND** Ri **AND** Fe

3.3. Development. In this phase, the conceptual designs of the E-Goat Doctor expert system were translated into a fully functional system using Swi-Prolog, a logic programming language specifically tailored for building rule-based expert systems. Swi-Prolog was chosen for its strong inference engine, which efficiently handles the rule-based logic required for diagnosing goat diseases. The following screenshots showcase the implementation of these rules and the overall structure of the system.

Fig. 3. Screenshots on the development of E-Goat Doctor Expert System

4. Results and Discussion

The E-Goat Doctor expert system was successfully developed to diagnose common goat diseases. Testing showed that the system accurately identified diseases like mastitis, foot rot, pneumonia, and worm infestation based on user-provided symptoms (see figure 5). The rule-based approach allowed the system to efficiently match symptoms with the appropriate disease, ensuring accuracy. The system's ease of use makes it especially beneficial for goat farmers in rural areas with limited access to veterinary services. The flexibility of the rule-based algorithm also means the system can be easily updated with new knowledge, enhancing its effectiveness over time.

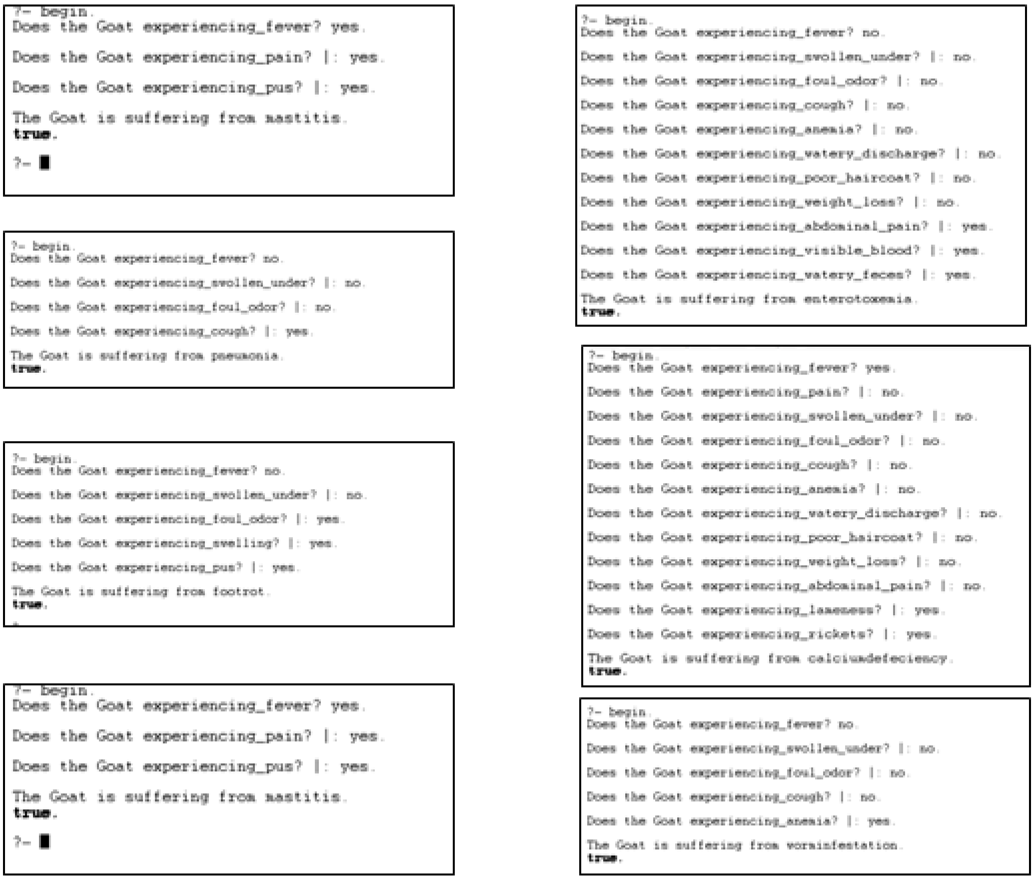

Fig. 4. Testing output of E-Goat Doctor Expert System

5. Conclusion and Recommendation

The development of the E-Goat Doctor expert system has shown that rule-based algorithms can effectively diagnose common goat diseases. This system provides a reliable, easy-to-use tool that can help farmers manage goat health more efficiently, particularly in areas with limited veterinary support.

Based on the results, it is recommended that the E-Goat Doctor be made available to goat farmers, especially in rural regions. Future work could focus on expanding the knowledge base to include more diseases and symptoms, as well as integrating the system with mobile platforms to increase accessibility.

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