SE-DiagEnf: An Ontology-Based Expert System for Cattle Disease Diagnosis

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Abstract. Cattle husbandry industry is an important development sector in many countries around the world. One of the main problems in this sector concerns cattle diseases which result in low productivity. A rapid diagnosis of the disease is particularly important for its prevention, control, and treatment. However, the main players on cattle husbandry industry highly depend on veterinarians to cope with this problem. Unfortunately, the number of veterinarians in some cities is very limited or they live far away from the farm. In this sense, it is necessary to provide farmers tools that help them to correctly diagnose the cattle diseases. Nowadays, there are technologies that can help to address this issue. On the one hand, expert systems are an active research area for medical diagnosis and recommending treatments. On the other hand, ontologies can be used for modeling the domain of cattle diseases diagnosis and for generating the knowledge base that is required by the expert system to perform its corresponding tasks. In this work, we present SE-DiagEnf, an ontology-based expert system that diagnoses cattle diseases based on a set of symptoms and provides recommendations for tackling the disease diagnosed. The main goal of this system is to decrease the dependency of farmers on veterinarians to cope with cattle diseases diagnosis and treatment. SE-DiagEnf was evaluated by farmers from Ecuador. In this evaluation, farmers had to provide a set of symptoms to allows the system to diagnose the cattle disease. The evaluation results seem promising based on the F-measure metric.

Keywords: Ontology · Cattle · Disease diagnosis

1 Introduction

Cattle husbandry industry is an important development sector in many countries around the world, in fact, cattle is one of the main sources of meat, milk, and labor [1]. One of the main problems in this area concerns the diagnosis and treatment of the diseases,

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indeed, cattle diseases result in low productivity in cattle husbandry sector. Therefore, a rapid diagnosis of cattle diseases is particularly important for their prevention, control, and treatment. However, the main players on cattle husbandry industry highly depend on veterinarians to cope with this problem. Unfortunately, the number of veterinarians in some cities is very limited or they live far away from the farm. Furthermore, since the disease cannot be accurately diagnosed by farmers, they use medicines or antibiotics that are not prescribed by experts. This situation can result in a significant impact on the ecological environment and food safety [2, 3]. In this sense, it is necessary to provide support to the cattle husbandry industry, particularly for the cattle diseases diagnosing. Indeed, the research of diagnostic, prevention and treatment methods and technologies for cattle diseases has become a priority among various research institutions.

Nowadays, there are a lot of technologies that can help to deal with the problem above mentioned. For instance, expert systems are an active research area as a mean for medical diagnosis and recommending treatment [4]. According to Darlington [5], an expert system is a program that attempts to mimic human expertise by applying inference methods to a specific body of knowledge. Hence, an expert system could help farmers to analyze the cattle health status and diagnose the disease without needing a veterinarian. On the other hand, ontologies are the main semantic web technology that allows computers to automate, integrate, and reuse high-quality information from distributed data sources [6]. Studer et al. [7] define an ontology as a formal and explicit specification of a shared conceptualization. Ontologies have been successfully applied in a variety of domains such as question-answering systems for Semantic knowledge bases [8], finances [9], and human resources management [10], to mention but a few. In this context, ontologies can be used for modeling the domain of cattle diseases diagnosis and for generating the knowledge base that is required by the expert system to perform its corresponding tasks.

Based on the fact described above, in this work, we propose the use of Information Technology (IT) to develop an intelligent system for cattle diseases diagnosis as well as for providing recommendations for tackling the diseases. The system determines the disease based on a set of symptoms provided by the farmer. The main goal of this system is to decrease the dependency of farmers on veterinarians to cope with cattle diseases diagnosis and treatment. In this way, the number of death cattle can be reduced.

The remainder of this paper is structured as follows: Sect. 2 discusses a set of systems for cattle diseases diagnosis that use multiple technologies such as fuzzy neural networks. Then, Sect. 3 details the components of the SE-DiagEnf architecture, whereas Sect. 4 addresses the evaluation performed to test the effectiveness of SE-DiagEnf in terms of efficacy regarding cattle disease diagnosis. Finally, Sect. 5 discusses the research conclusions and future directions.

2 Related Work

Because of the advances in hardware and software as well as processing capabilities, many researchers have proposed expert systems to improve animals' disease diagnosis. For instance, Jampour et al. [11] presented a Fuzzy-based system for diagnosing domestic animal diseases. This system uses neurological signs to reduce natural uncertainty regarding the diagnosis of the disease. On the other hand, Munirah et al. [12] proposed a Web-based expert system for dog's diseases diagnosis. This system aims to detect disease in an early stage and assist owners by providing them treatment suggestion. The system has a knowledge base with rules of symptoms and diseases. These rules use an IF/THEN structure where the information contained in the IF clause is related to the information contained in the THEN clause. Finally, it should be mentioned that all knowledge used by this system is obtained from a set of interviews performed to veterinarians.

There are research efforts focused on cow disease diagnosis, for instance, Zamsuri et al. [1] presented a Web-based expert system to determine the cow disease based on a set of symptoms experienced by animals. These symptoms are obtained through a set of questions that farmers must answer. To deal with uncertainty, this system conducts the diagnostic process using Certainty Factor. Furthermore, a set of rules for disease diagnoses have been made in accordance with the experts' knowledge. Nusai et al. [13] presented a cow diseases diagnosis method that consists in two phases namely: disease screening and disease diagnosis. Also, they proposed a knowledge model to infer the disease through variables such as gender, age range, and a weight of symptom to deal with uncertainty. In this way, the method uses the significant weight of symptom and the certainty factor of symptom to perform disease diagnosis. On the other hand, Lian et al. [14] consider that animal disease diagnosis is a pattern classification and identification problem. Therefore, they proposed a model for cow disease diagnosis that uses SVM (Support Vector Machine) and HSMC (Hyper Sphere Multiclass SVM) technologies. This model consists of three main modules namely preprocessing module, HSMC-SVM training module, and HSMC-SVM classification module. More specifically, this model implements the SMO (Sequential Minimal Optimization) training algorithm to train to classify types of animal diseases. Zhang et al. [15] established an evidence-weighted uncertainty illation model able to deal with uncertainty in the cow disease diagnosis process. Firstly, this model reasons out a hypothetical conclusion based on the initial symptoms. Then, it performs a backward inference to reason out the final diagnosis by validating the hypothetical conclusion. Wan et al. [16] designed an SVM (Support Vector Machine) based model for cow disease diagnosis. The model consists in a data preprocessing module, a training module, and a classification of a multi-value module. Furthermore, this model defines a separate SVM for each disease according to its category, then all classified SVM are integrated and combined into an SVM classification group. Finally, Rong et al. [17] proposed a Web-based expert system for cow disease diagnosis. This system implements an inference engine for disease diagnosis that is based on three algorithms namely: case-based reasoning, Bayesian theory, and D-S evidential theory. Furthermore, sometimes the user can choose one of these algorithms to get a reliable diagnostic result.

Regarding goat diseases diagnosis, Wenxeu et al. [18] proposed a goat diseases diagnosing mechanism based on two algorithms namely weighted uncertainty reason algorithm and the improved Bayesian method. This mechanism uses clinical models, disease templates and cases of sampled diseases to extract knowledge rules which are used by reasoning-components for the diagnosis process. Xiao et al. [19] proposed an animal diagnosis system composed of three main elements namely: a disease case management system, a knowledge management system, and an expert system. This system uses an augmented knowledge representation based on production rules to perform the diagnosis process. Finally, Babu et al. [20] presented an expert system to diagnose sheep and goat diseases. This system uses a sheep and goat diseases database implemented by means of rule-based techniques and machine-learning algorithms, more specifically ABC (Artificial Bee Colony) and PSO (Particle Swarm Optimization). When the system cannot diagnose the disease, it displays a message saying that knowledge is not enough to perform such task.

On the other hand, there are some works focused on aquatic animals' diseases diagnosis. For instance, Sun et al. [21] present an Android-based application for diagnosing aquatic animal diseases. This application diagnoses an animal disease by using a case-based inference engine in conjunction with an expert symptom scoring method. Both methods are used at the same time. However, when the diagnostic results of these methods are different, the system asks the farmer for feedback until he/she is satisfied with the result. Deng et al. [22] proposed a fish disease diagnosis expert system based on a three layers neural network. This system uses old cases of fish diseases to train the neural network i.e., it uses diagnostic instances provided by fish disease experts. In this way, when a new diagnostic instance is provided to the system, it infers the disease. Fish disease diagnosis is based on the fish symptoms and the anomaly of the water environment. Finally, Ma et al. [23] presented a Multi-agent based expert system for distributed fish diseases diagnosis. This system implements a module known as Computing Agent that allows the distributed diagnosis and management of fish diseases and decrease the flow of raw data on the network, thus reducing the network load.

Finally, with regards to cattle and swine diseases diagnosis, Anggraeni et al. [24] presented an Android-based mobile intelligent system for diagnosing cattle diseases as well as suggesting first aid actions. The intelligent engine of this application relies on Fuzzy Neural Network (FNN) as well as rule-based and frame-based techniques for representing the knowledge. In rule-based approach, the knowledge is represented as a set of rules. Meanwhile, in frame-based approach, knowledge is represented as a set of objects. On the other hand, Nusai et al. [25] presented an expert system for swine disease diagnosis. This system uses a weight-based method that assigns a weight to each symptom, which is defined by a veterinarian. Furthermore, the system provides a set of pictures and a description of each symptom to allow the user to specify the certainty factor correctly.

The works described in this section are focused on the development of expert systems for animals' diseases diagnosis. The authors of these works proposed solutions based on a variety of technologies such as machine learning, fuzzy neural networks, among others. Note that most of the examined methods or systems don´t focus on cattle disease diagnosis. Also, disease diagnosis using ontologies is not specially reported in these works. SE-DiagEnf addresses these drawbacks by means of a modular expert system, whose main goal is to provide farmers support for cattle diseases diagnosis. To achieve this goal, SE-DiagEnf uses veterinarians' knowledge and experience to establish a set of rules that help to diagnose the cattle disease based on a set of symptoms provided by the farmer. The experts' knowledge is represented by means of Semantic Web technologies, more specifically ontologies. In the following section, the components of SE-DiagEnf and their interactions are thoroughly explained and described.

3 SE-DiagEnf: Architecture and Functionality

SE-DiagEnf is an expert system that relies on Semantic Web technologies for cattle diseases diagnosis. Furthermore, this expert system provides farmers with treatments for tackling the diagnosed disease. The development process of SE-DiagEnf followed the knowledge engineering methodology proposed in [26]. This methodology consists of six phases namely: problem assessment, data and knowledge acquisition, prototype development, complete system development, system evaluation, and integration and maintenance of the system. For the purposes of this work, only first five phases were performed, since integration and maintenance phase will depend on the organization that adopts our proposal.

3.1 SE-DiagEnf Architecture

The SE-DiagEnf's architecture is illustrated in Fig. 1. Note that this architecture has next three main components:

1. Ontology. It models the cattle diseases diagnosis domain through concepts such as disease, symptom, body system, treatment, among others.
2. Rule-based engine. It contains a set of rules for cattle diseases diagnosis. These rules are defined by using knowledge and information obtained from several sources such as books about cattle diseases and treatments, as well as from veterinarians with a wide expertise on the diagnosis and treatment of cattle diseases.
3. Cattle disease treatments database. It stores cattle disease treatments that will be provided by the system once the disease has been diagnosed.

It must be mentioned that each component of SE-DiagEnf has tasks and responsibilities clearly defined and distributed in order to allow easy maintenance and scalability. Furthermore, the workflow of SE-DiagEnf is defined by a set of interrelationships between such components. This workflow is briefly described below:

1. The first task of the workflow is performed by the farmer who collects all symptoms that perceives in the cattle and provides them to the system.
2. SE-DiagEnf receives the set of symptoms and diagnoses the cattle disease by using the experts' knowledge that is already available in the system in the form of rules. More specifically, this process is performed through the rule-based engine.

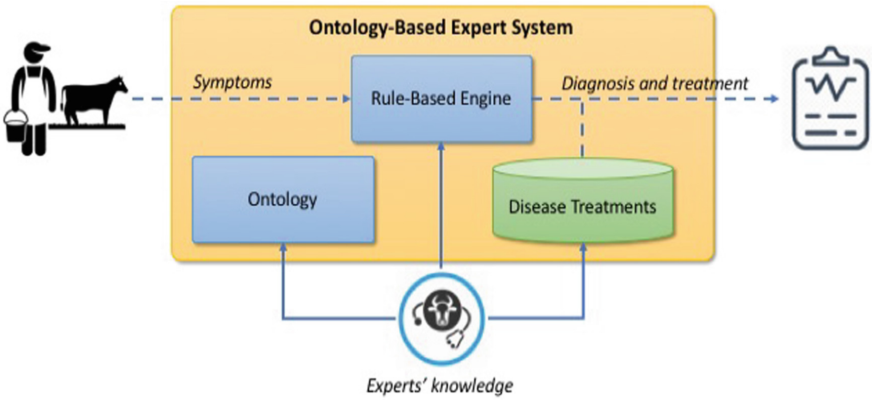

Fig. 1. Architecture of the ontology-based expert system for cattle diseases diagnosis.

3. If the symptoms provided by the farmer matches to the rules available in the knowledge base, the system displays the disease that cattle are suffering. However, when the set of symptoms does not match a rule, the system asks the user for more information.
4. Once the disease has been diagnosed by the system, it provides a treatment that can be followed by farmers to deal with the diagnosed disease.

Next subsections provide a more detailed description of the ontology for cattle disease diagnosis and the rule-based engine.

3.2 Ontology

The development of SE-DiagEnf required a knowledge acquisition process to gather experiences and knowledge from several domain experts, in this case, from veterinarians with a wide experience on cattle diseases diagnosing and treatment. Aiming to formally represent all gathered knowledge, an ontology was designed and implemented by using the OWL 2 Web Ontology Language [27]. The goal of this ontology is to provide a controlled vocabulary for cattle disease diagnosing as well as diseases treatments. This vocabulary allows experts to establish the set of rules that enables SE-DiagEnf to diagnose the correct cattle disease based on a set of symptoms provided by the farmer. The ontology presented un this work defines five main classes, namely: Disease, Symptom, Age range, Body System, and Treatment. All these classes were defined as disjoint classes, i.e. there is no instance belonging to all these classes. The classes defined by this ontology are described below.

- Disease. A disease is a disorder of structure or function in an animal that produces specific signs or symptoms or that affects a specific location. In this ontology, animal diseases are divided into infectious and noninfectious. Furthermore, non-infectious diseases can be further divided into nervous system disease, respiratory system, digestive system, to mention but a few. The first version of the ontology collects information about diseases such as ketosis, milk fever, mastitis, anaemia, food and mouth disease, among others.

- Symptom. A symptom is a phenome accompanying something, in this case, a cattle disease, and is regarded as evidence of its existence [28]. The ontology developed in this work describes 76 symptoms related to the diseases also described by it, such as watery yellowish diarrhea, dehydration, tremor, edema, vomiting, mucohemorrhagic, depressed appetite, reduced feed intake, among others.
- Age range. It includes five main age ranges: born, pre-weaning, post-weaning, puberty, and breeding.
- Body system. A body system is a collective functional unit made by several organs in which the organs work in complete coordination with one another. This class includes different body systems where symptoms occur such as digestive, nervous, respiratory, reproductive, urinary, circulatory, endocrine and muscular.
- Treatment. A treatment is an effort to cure or improve a disease or other health problem. In the medical domain, therapy is synonymous with the word treatment.

Despite the ontology proposed in this work describes relatively few cattle diseases and symptoms, it could be extended by veterinarians aiming to cover a wider range of diseases, including disease of other animals.

3.3 Rule-Based Engine

Animal diseases can be diagnosed by identifying a set of symptoms, thus allowing to control and treat the disease. However, there are symptoms that are related to more than one disease, thus making this process a complex task that cannot be performed by non-expert people. Considering this fact, in this work, we propose a rule-based engine that takes advantage of domain experts knowledge represented by means of semantic technologies, more specifically, ontologies. In other words, the ontology proposed in this work is the main source of computable knowledge that is exploited by the expert system to diagnose the cattle disease.

In the area of Artificial Intelligence, knowledge rule is the prime form to represent human knowledge [18]. Therefore, SE-DiagEnf adopts this approach to represent the relation between symptoms and cattle diseases i.e., we transfer the knowledge that experts have (which is represented by the ontology) into a set of rules that allows diagnosing cattle diseases based on a set of symptoms experienced by the animal which are provided by the farmer. In other words, the main task of the rule-based engine is to simulate experts' reasoning process based on a set of rules.

As was previously mentioned, there are symptoms that are related to more than one disease. However, there are symptoms that are more important than other ones i.e. a symptom can help more than any other symptom in diagnosing a disease. In an attempt to address this situation, we asked veterinarians to assign a significant weight to each symptom. In this way, when a symptom helps more than any other symptom, it has a greater weight. Furthermore, it should be noted that the weight assigned to each symptom varies from one disease to another one.

The rules established in this work were defined by using the SWRL language [29]. These rules are represented according to the format presented in Eq. 1:

$$R_1, R_2, R_3, \ldots, R_n \rightarrow D \quad (1)$$

Where *R* represents a condition that must be met to diagnose a disease. Meanwhile, *D* represents the disease that is diagnosed when all conditions are met. To be more specific, the disease diagnosing process performed by the rule-based engine works as follows. First, the user must provide specific information about the animal, for instance, the age and gender of the animal, the animal body temperature, salivary secretion, among others. Then, the user must provide the system all animal's symptoms as well as the body system where they occur. It is important to mention that each of the aforementioned data (age, gender, body temperature, symptom, among others) represent a condition (*R* in Eq. 1) that must be met to infer the disease. Having said that, once all information is provided by the farmer, SE-DiagEnf infers the disease based on the set of rules previously defined. There are different rules that can be applied to the set of symptoms provided by the user. However, the weight associated with each symptom plays an important role in the final diagnosis. Once disease diagnosis process finishes, the system provides farmers information about the cattle disease such as symptoms, prevention guides, animal care guides, as well as disease treatments. Next section provides a description of the evaluation process performed in this work to measure the effectiveness of SE-DiagEnf regarding cattle disease diagnosis.

4 Evaluation

The evaluation described in this section aims to measure the efficacy of SE-DiagEnf regarding cattle disease diagnosing. In other words, we assess how effective our proposal is in diagnosing a cattle disease based on a set of symptoms and animal's information provided by the farmer. The following sections describe the evaluation design and discuss the obtained results.

4.1 Evaluation Design

To evaluate SE-DiagEnf, we conducted an experiment that required 100 medical records with information regarding the animal (such as age and gender, among others), as well as the symptoms perceived by the veterinarian during disease diagnosis process. These medical records were provided by a group of veterinarians with a wide experience in the diagnosis and treatment of cattle diseases. The data used in this evaluation process covers five different cattle diseases (20 medical records by each disease) namely:

1. Ketosis. It is a common disease of adult cattle. It is a metabolic disease that occurs when the cow is in a severe state of negative energy balance.
2. Milk fever. It is a disorder mainly of dairy cows close to calving. It is a metabolic disease caused by a low blood calcium level.

3. Mastitis. It is a persistent, inflammatory reaction of the udder tissue due to physical trauma or microorganisms' infections.
4. Anaemia. It is often caused by bush ticks that attach themselves to the livestock. This disease is common among young calves 8–12 weeks old but can affect cattle of all ages.
5. Foot and mouth disease. It is a highly contagious disease in livestock that causes lesions similar to blisters on the tongue, nose, mouth and toes of the animals.

Once the set of medical reports were collected and classified, we extract the information about the animal (such as age and gender, among others), as well as the symptoms described in the medical records. The extracted information was provided to SE-DiagEnf as input. Then, SE-DiagEnf performed the disease diagnosis process based on the rules established. Finally, the SE-DiagEnf efficiency regarding disease diagnosis was measured through accuracy metric whose formula is shown in Eq. 2.

$$\text{Accuracy} = \text{C/A} * 100 \tag{2}$$

Where *C* refers to the correctly diseases diagnosed. Meanwhile, *A* refers to the total of diseases diagnosed. Next section presents and discusses the evaluation results.

4.2 Evaluation Results

Table 1 depicts the evaluation results obtained by SE-DiagEnf. As can be observed, our proposal got an average accuracy score of 77%. The cattle disease that got the highest accuracy score was the ketosis, with a score of 85%. Meanwhile, the cattle disease with lowest accuracy score was Anaemia, with a score of 70%.

Table 1. Evaluation results

Heading level	Accuracy
Ketosis	85%
Milk fever	75%
Mastitis	80%
Anaemia	70%
Food and mouth disease	75%
Avg.	77%

The evaluation results demonstrating a good effectiveness of SE-DiagEnf regarding cattle disease diagnosis. However, based on a detailed analysis of all medical records used in the evaluation process we ascribe the variations among the accuracy scores obtained by each disease to next facts:

1. The known set of symptoms cannot match with any rule in the semantic knowledge base. In this case, the system cannot diagnose a disease because of the lack of rules in the knowledge base.

2. The known set of symptoms match with many rules, or there were many known symptoms which can match with one rule. In this case, because there are several rules that use the same symptoms, the system cannot determine which rule should be used, i.e. which disease must be provided to the farmer as result.

Finally, we observed that the diagnosis process performed by SE-DiagEnf is more precise when the set of symptoms provided to the system is bigger. However, there were different symptoms described in the medical records are not contained in the ontology. In this sense, it is necessary that the ontology proposed in this work describe more disease and symptoms, as well as to include their synonyms and jargon, i.e. special words used by veterinarians in the disease diagnosis process. In this sense, it would be desirable to extend the ontology regarding the set of diseases and symptoms. This, in turn, will allow us to generate a bigger set of rules that improve the effectiveness of our proposal.

5 Conclusions

This work presented SE-DiagEnf, an ontology-based expert system for cattle diseases diagnosis. The core engine of this system was implemented by using Semantic Web technologies, more specifically ontologies and SWRL language. Our proposal takes advantage of experts' knowledge collected from several sources such as books about cattle diseases and treatments, as well as from veterinarians. This knowledge was model by means of an ontology from which a set a set of rules for cattle disease diagnosis were generated. The main goal of SE-DiagEnf is to decrease the dependency of farmers on veterinarians to cope with cattle diseases diagnosis and treatment. The expert system proposed in this work was evaluated obtaining encouraging results with an accuracy score of 77% for five common cattle diseases. The contribution of this work is twofold. First, we propose an ontology for describing the cattle diseases diagnosis domain through concepts such as symptoms, diseases, body system, treatment, among others. Second, a set of rules for cattle disease diagnosis has been developed.

Further development of the expert system proposed in this work will focus on the following scopes. The first version of SE-DiagEnf can diagnose only five cattle diseases. As future work, we are planning to enhance the system to deal with other diseases whose symptoms are rarer. Furthermore, in order to improve the accuracy of cattle disease diagnosing we are planning to add new rules that consider a bigger set of symptoms as well as animal's features such as weight, breathing, pulse, among others. Furthermore, we are planning to integrate images with the experts' knowledge to help farmers describing the symptoms, thus making SE-DiagEnf more user-friendly. Finally, we plan to include living environment information to the disease diagnosis process such as weather, water, grass, among others. This information could help to determine the cause of the disease and to select the right medicine, thus improving the effectiveness of the treatment.

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