Expert systems for diagnostics of infectious diseases in cattle

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Abstract. Expert systems designed to identify diseases in cattle may use a variety of sources of information such as clinical data, signs of disease, medical history, laboratory results, environmental exposure and other relevant factors. They can be developed based on rules, heuristics, or machine learning, using a large amount of data to train the model. The expert system may provide the veterinarian with a list of possible diagnoses, ranked by probability, based on the data provided. She may also recommend further investigations or tests for a more accurate diagnosis. The developed expert system for veterinary medicine provides a wide range of functions and capabilities to support the work of veterinarians and processing data on the incidence of cattle.

1 Introduction

Veterinary medicine is an important area of animal health care, and the development of expert systems for diagnosing diseases is becoming an increasingly common practice. Expert systems are software tools that use the knowledge and experience of experts in a particular field to make decisions and provide recommendations [1].

When developing an expert analysis system for identifying diseases in cattle, the goal may be to assist veterinarians in identifying potential diseases by analyzing symptoms, clinical data and laboratory results. This enables veterinarians to receive accurate and prompt diagnoses, which in turn helps them choose the most effective treatment methods [2]. The use of expert systems in veterinary medicine has the advantage of retaining and transferring knowledge. These systems are able to store the expertise and experience of veterinarians, allowing them to be effectively transferred to other professionals and used in future cases of diagnosis and treatment. Expert systems in veterinary medicine can be updated and supplemented with new knowledge and experience of veterinarians. This allows systems to update their knowledge base with new scientific discoveries, developments and clinical observations, resulting in an increased ability to accurately diagnose and offer the most effective treatment. Expert systems for diagnosing diseases in cattle can greatly facilitate the work of veterinarians and reduce the risk of misdiagnosis.

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They are one example of the use of modern technology and artificial intelligence to improve animal health [3].

The developed expert system for veterinary medicine provides a wide range of functions and capabilities to support the work of veterinarians and processing data on the incidence of cattle. Let's consider each of these functions in more detail [4] :

Support for up-to-date incidence data: The expert system allows you to store and update data on the incidence of cattle in real time. This may include information about clinical observations, laboratory test results, treatment history, and other relevant data. Maintaining up-to-date data allows veterinarians to have a complete overview of the status of the herd and respond to emerging problems in a timely manner.

Operational and complex analysis of the condition of animals: The expert system allows for an operational analysis of the condition of cattle based on the data provided. The system can use the knowledge and experience of experts to automatically assess the condition of animals, identify potential diseases and prioritize further intervention. In addition, the system can carry out complex analysis considering various factors such as age, gender, weather and housing conditions to get a more complete picture of the condition of the herd.

Diagnostic and prophylactic surgery: The expert system can offer recommendations to veterinarians for diagnostic and prophylactic surgery based on the analysis of data and symptoms. It may offer a list of possible diagnoses, recommendations for laboratory testing and testing, and suggestions for preventive measures such as vaccinations or deworming.

Standard reporting and data visualization: The expert system can generate standard reporting based on the results of analysis of observational data. Reports may contain information on incidence, the prevalence of specific diseases, the effectiveness of treatment, and other indicators. In addition, the system can provide visualization of results, such as graphs or charts, to help veterinarians quickly assess the situation and make informed decisions.

2 Materials and methods

Production models of knowledge representation are one of the most common and effective approaches in the development of expert systems. They include several key components that ensure the representation and use of knowledge in the system [5].

Production Rules: Production rules are the foundation of the production model. They consist of conditions and associated actions. Conditions describe the facts or states that must be true for the rule to apply, and actions define what must happen if the conditions are met. Production rules allow the system to draw conclusions and make decisions based on existing knowledge.

Working memory: Working memory is a store of facts or states used by the system to apply production rules. It contains current information about the task or environment in which the expert system operates. Working memory is updated and modified during system operation and is used to activate and apply production rules.

Condition-Action Loop: The Condition-Action Loop is the core mechanism of the production model. In this cycle, the system checks the conditions of the production rules based on the contents of the working memory. If the conditions of the rules are met, the corresponding actions are activated and executed. Then the state of working memory is updated and the process is repeated until the required state or solution of the problem is reached.

Production models of knowledge representation have a number of advantages, such as flexibility, easy interpretation, the ability to easily change or add rules, and the ability to use different inference strategies. They are widely used in expert systems for solving various problems, including diagnostics, planning, and decision making [6].

We will assume that there is a sample of experimental data on cattle diseases that connects the inputs $X = (x_1, x_2, ...x_{rn})$ with the output y of the studied dependence [7]:

$$(x_r, y_r), (r = \overline{1, M}) \tag{1}$$

Where $X_r = (x_{r,1}, x_{r,2}, ...x_{rn})$ vector of inputs and y_r output in *r*-pair; M- sample size.

We construct the Mamdani model as follows [8-11]:

If $(x_1 = a_{1,j1}) and, (x_1 = a_{2,j1}) and....and (x_n = a_{n,j1})$ with weight ω_{j1}

Or $(x_1 = a_{1,j1}) and, (x_2 = a_{2,j1}) and....and (x_n = a_{n,j2})$ with weight ω_{j2}

Or $(x_1 = a_{1,jk_j}) and, (x_2 = a_{2,jk_j}) and....and (x_n = a_{n,jk_j})$ with weight ω_{jk_j}

Than $(y = d_j, j = \overline{1, m})$

Where *a* -linguistic term, which allows you to express a qualitative assessment or the degree of membership of a variable x_j to a certain linguistic concept: j, jp = category represented in the line *jp* , $p = \overline{1, k}$; k_j = number of conjunction strings with linguistic evaluation d_j for output *y;* ω_{jp} = rule weight. It represents a numeric value that determines the importance or weight of the given jp *rule* in the context of the system m- the number of terms.

To create a more compact representation of a fuzzy knowledge base using the $\bigcup$ (OR) and $\bigcap$ AND) operations, we can combine several rules into one using these operations:

$$\bigcup_{p=1}^{k_j} [\bigcap_{i=1}^{n} (x_i = a_i^{jp})] \to y = d_j, j = \overline{1, m} \tag{2}$$

The use of the following notation will help us shorten the record of the fuzzy knowledge base, make it more compact and easy to understand [12-13]:

$\mu_{jp}(x_i)$ -membership function, which determines how much the input parameter x_i corresponds to a certain fuzzy term $a_i jp$,

$$i = \overline{1, n},\ j = \overline{1, m},\ p = \overline{1, k_j},\ a_{i, jp} = \int_{\underline{x_i}}^{\overline{x_i}} \mu_{jp}(x_i) / x_i, x_i \in [\underline{x_i}, \overline{x_i}]$$

$\mu d_j(y)$-Membership function, which is a mathematical function that determines how much the output signal *y* corresponds to a certain fuzzy term d_j, i.e.

$$d_j = \int_{\underline{y}}^{\overline{y}} \mu d_j(y) / y, y \in [\underline{y}, \overline{y}]$$

$$\mu d_j(X^*) = \underset{i=1,n}{\vee} \omega_{jp} \cdot \underset{i=1,n}{\wedge} [\mu j_p(X^*)], i = \overline{1, m} \tag{3}$$

$$y = \underset{j=1,m}{\underline{agg}} (\int_{\underline{y}}^{\overline{y}} imp(\mu_{dj}(X^*), \mu_{dj}(y) / y)$$

Where imp implication agg- aggregation of fuzzy sets.

3 Results and Discussion

Using the fact base as part of the knowledge base in expert systems is a common approach. The fact base is a collection of information or data about the state of objects or facts in a given subject area. When diagnosing diseases in cattle, the fact base can contain a variety of information, including symptom data, laboratory test results, medical history and other facts that play an important role in the diagnosis process. [14-15].

Associating facts in a fact base with a user interface allows you to create a system that can receive information from the user and use it to make a diagnosis or provide recommendations. User can enter status data cattle, its symptoms or disease history through an interface, and the system can link this data to facts in the fact base to diagnose and provide information about possible diseases or treatments.

This approach allows the system to use existing knowledge about the diagnosis of diseases in cattle and combine it with up-to-date data on the condition of the animal received from the user. This contributes to a more accurate diagnosis and the provision of more personalized recommendations to veterinarians or users of the system.

The user interface may provide a convenient means of data entry, the ability to ask questions or receive explanations from the system. The user can interact with the system, provide additional data or clarifications, and the system, in turn, can use this data to clarify the diagnosis or provide more detailed information.

This interaction between the fact base and the user interface allows for a more flexible and intelligent dairy cow disease diagnosis system that takes into account both existing knowledge and up-to-date data, and allows users to effectively interact with the system to obtain the necessary information and recommendations.

The process of acquiring knowledge to create a knowledge base includes three stages, each of which performs certain functions.

Pre-acquisition and triage of baseline knowledge: In this step, baseline knowledge related to the diagnosis of diseases in cattle is collected. This may include scientific publications, medical and veterinary sources, empirical data, etc. Knowledge may be presented in a variety of formats such as text documents, studies, articles, and expert opinions. When collecting initial knowledge, it is initially sorted and evaluated to determine its relevance and usefulness for the purposes of the system.

Processing and analysis of background knowledge: In this stage, specialists in the disciplines of veterinary medicine work with background knowledge. They conduct a detailed analysis of the source data, identify key facts, determine the relationships between them and structure the knowledge gained. This process may include the interpretation, classification, aggregation and annotation of knowledge. Specialists can use their experience and expert opinion to carefully analyze and interpret the source data.

Expert Analysis and Evaluation: In this step, the evaluation team analyzes the processed knowledge and generates data to create a knowledge base. Experts can check and confirm the reliability and accuracy of knowledge, its compliance with modern practices and standards of veterinary medicine. They can also make further adjustments and recommendations based on their experience and expertise. This stage ensures the high quality and reliability of the knowledge base before its use in the expert system.

As a result of these three stages, a knowledge base is formed, which is the basis for the work of an expert system for diagnosing diseases of dairy cows. The knowledge base contains the structured and organized data, rules, and facts needed to make decisions and provide recommendations. This allows the system to quickly and accurately diagnose, as well as maintain the relevance of knowledge in future work.

One of the important steps in creating a knowledge base for an expert system related to the diagnosis of cattle is to obtain information about infectious and non-infectious etymology. The collected data on the infectious and non-infectious etymology of cattle play an important role in the training of the expert system. This information allows the system to recognize and classify various diseases based on symptoms, causes, and treatments, and provide relevant information and recommendations to veterinarians. By analyzing and processing this data, an expert system can establish links between various factors and diseases, identify characteristic signs and symptoms, and determine the best treatments. This allows the system to make more accurate and reliable diagnoses, as well as offer appropriate recommendations to veterinarians for the treatment and health management of cattle.

Questioning of veterinarians allows you to get the expert opinion and experience of professionals who work in this field. Questions may relate to typical symptoms, treatment, diagnostic methods and other aspects related to the infectious and non-infectious etymology of cattle. This allows you to collect valuable information and knowledge based on the practical experience and expertise of veterinarians.

The analysis of reference data in the field of veterinary medicine complements the data received from veterinary specialists. These can be scientific publications, medical and veterinary manuals, statistics and other information sources that contain information about various diseases and their etymology in cattle. The analysis of these data helps to establish links and trends between various diseases, as well as to collect reliable facts that will be used to form a knowledge base.

The collected data on infectious and non-infectious etymology of cattle after processing and analysis will be used to create rules, facts and relationships in the knowledge base of the expert system. This will allow the system to diagnose, provide recommendations for treatment and prevention of diseases, and ensure the relevance and reliability of information based on expert experience and scientific data.

The division of knowledge into different structural levels depending on the age of cattle can be useful in diagnosing diseases and improving the efficiency of the expert system. Different age groups of cattle can be susceptible to different types of diseases and have different manifestations of disease, so taking age into account in diagnosis is an important factor.

Separating knowledge by age group allows the system to more accurately focus on typical diseases and symptoms associated with each age group of cattle. For example, newborn calves may have specific diseases and problems related to the immune system and digestive system, while adult cattle may have more common diseases such as mastitis or metabolic disorders. The division of knowledge into different age groups allows the system to take into account these features and provide more accurate recommendations and diagnostic solutions.

The efficiency of the system is improved by narrowing the search space during the diagnostic process. This allows more efficient use of resources and reduces the time required to search and process information, increasing the accuracy and speed of diagnostics.

Thus, the division of knowledge into different structural levels depending on the age of cattle helps the system take into account the specifics of age groups, improves the diagnosis of diseases and increases the efficiency of the system as a whole.

The process of diagnosing a disease in cattle includes several stages, including clinical examination, history taking, laboratory and instrumental studies. Here is an example protocol for diagnosing a disease in cattle:

Clinical examination: The veterinarian examines the animal, evaluates its general condition, behavior, appetite, body temperature, swelling, discharge, changes in appearance and other symptoms. It is important to provide the veterinarian with all available information about the animal, such as timing of symptoms, contact with other animals, etc.

Laboratory research:

Blood Tests: Includes CBC, biochemistry, antibody testing, and other specific tests depending on the suspected disease. These tests can help detect inflammation, changes in blood composition, and the presence of pathogens.

Bacteriological examination: If an infectious disease is suspected, excreta samples (milk, feces, urine, etc.) may be taken to grow and identify bacteria or other microorganisms.

Serological tests: Can be used to detect antibodies that develop in response to a specific infection. These tests can help determine the presence or absence of specific infections.

Molecular tests: For example, polymerase chain reaction (PCR) can be used to detect and identify the genetic material of pathogens such as viruses or bacteria.

Instrumental research:

Ultrasound: Can be used to evaluate internal organs, look for abscesses, tumors, or other changes.

Radiology: Used to diagnose bone lesions, tumors, pneumonia and other changes.

The veterinary specialist, based on the results of all the studies carried out, will make a diagnosis and develop a treatment and prevention plan, taking into account the nature of the disease, its stage and the characteristics of each individual case. It is important to consult an experienced veterinarian for the diagnosis and treatment of bovine disease.

The main signs of infectious diseases in cattle may include:

Fever: The animal may have an elevated body temperature, which may be a sign of an infectious process.

Loss of Appetite: Infectious diseases can lead to a decrease in the animal's appetite, resulting in reduced feed intake.

Fatigue and weakness: Infectious diseases are often accompanied by general weakness, fatigue and decreased activity of the animal.

Difficulty breathing: Some infectious diseases can cause breathing problems such as coughing, shortness of breath, or difficulty breathing.

Discharge: Infectious diseases may be accompanied by discharge from the nose, eyes, mouth, or genitals, such as mucus, pus, or blood.

Digestive changes: Infectious diseases can cause changes in the digestive system, such as diarrhea, constipation, vomiting, or changes in the consistency of bowel movements.

Weight Loss: Chronic or serious infectious diseases can lead to gradual weight loss in an animal.

Inflammation or swelling: Some infectious diseases can cause inflammation or swelling in certain areas of the body, such as the joints, udder, eyes, or skin.

Reduced productivity: Infectious diseases can lead to reduced milk production, growth, or other performance indicators in cattle.

It is important to note that the signs may vary depending on the specific disease and the individual characteristics of the animal. If you suspect an infectious disease in cattle, it is recommended that you contact your veterinarian for diagnosis and appropriate treatment.

In addition to the main signs, infectious diseases in cattle can also manifest additional signs, depending on the specific disease. Some of these may include:

Purulent growths: Some infectious diseases can cause purulent abscesses or ulcers to form on the skin, udder, nose, or other areas of the body.

Inflammation of the joints: Some infectious diseases can lead to inflammation of the joints, which is manifested by swelling, pain and limitation of movement.

Reproductive system diseases: Infectious diseases can affect the reproductive function of animals, manifested in the form of abortions, inflammation of the uterus, advanced postpartum period or other problems in the field of reproduction.

Nervous symptoms: Some infectious diseases can cause nervous symptoms such as seizures, paralysis, changes in behavior or coordination.

The classification of bovine infectious disease diagnostic results helps veterinarians make informed decisions about treatment, preventive measures and infection control :

- y_1 - Luellosis fever.
- y_2 - Pasteurellosis.
- y_3 - Chlamydia.
- y_4 - Foot and mouth disease (lichen).
- y_5 -Paratuberculosis.

When making a diagnosis, the following main parameters are taken into account

- x_1 - Temperature increase.
- x_2 - Decreased appetite.
- x_3 - Discharge from the nose.
- x_4 -Tracheitis.
- x_5 - Swelling and inflammation of soft tissues.
- x_6 -Deterioration of the general condition
- x_7 -Conjunctivitis.
- x_8 -Rhinitis.
- x_9 - Discharge from the eyes.
- x_{10} - Formation of round or oval foci of reddening of the skin with scales.
- x_{11} -Itching and discomfort.
- x_{12} -Loss of hair in affected areas.
- x_{13} -Slimming.
- x_{14} -Loss of appetite.
- x_{15} - Liquid stools.
- x_{16} - lingering diarrhea.
- x_{17} -Reduced productivity.

A fuzzy logical model of Mamdani was built from the main 17 factors:

If $x_1 = H \wedge x_2 = H \wedge x_3 = L \wedge x_4 = H \wedge x_4 = L \wedge x_5 = L \wedge x_6 = L \wedge x_7 = L \wedge x_8 = L \wedge x_9 = L \wedge x_{10} = L \wedge x_{11} = L \wedge x_{12} = L \wedge x_{13} = L \wedge x_{15} = L \wedge x_{16} = H \wedge x_{17} = L$

Then $y = y_1$

If $x_1 = H \wedge x_2 = H \wedge x_3 = L \wedge x_4 = L \wedge x_5 = H \wedge x_6 = H \wedge x_7 = L \wedge x_8 = L \wedge \wedge x_9 = L \wedge \wedge x_{11} = L \wedge x_{12} = L \wedge x_{13} = L \wedge x_{14} = L \wedge x_{15} = L \wedge x_{16} = A \wedge x_{17} = L$

Then $y = y_2$

If $x_1 = H \wedge x_2 = H \wedge x_3 = L \wedge x_4 = L \wedge x_5 = L \wedge x_6 = L \wedge x_7 = H \wedge x_8 = H \wedge x_9 = H \wedge x_{10} = L \wedge x_{11} = L \wedge x_{12} = L \wedge x_{13} = L \wedge x_{15} = L \wedge x_{16} = L \wedge x_{17} = L$

Then $y = y_3$

If $x_1 = L \wedge x_2 = L \wedge x_3 = L \wedge x_4 = L \wedge x_5 = L \wedge x_6 = L \wedge x_7 = L \wedge x_8 = L \wedge x_9 = L \wedge x_{10} = H \wedge x_{11} = H \wedge x_{12} = H \wedge x_{13} = L \wedge x_{14} = L\ x_{15} = L \wedge x_{16} = L\ x_{17} = L$

Then $y = y_4$

If $x_1 = L \wedge x_2 = L \wedge x_3 = L \wedge x_4 = L \wedge x_5 = L \wedge x_6 = L \wedge x_7 = L \wedge x_8 = L \wedge x_9 = L \wedge x_{10} = L \wedge x_{11} = L \wedge x_{12} = L \wedge x_{13} = H \wedge x_{14} = H \wedge x_{15} = H \wedge x_{16} = H \wedge x_{17} = H$

Then $y = y_5$

It is important to remember that these are just some of the possible infectious diseases in cattle and each disease can have its own unique characteristics.

4 Conclusion

The Expert System is a powerful tool for veterinarians to help them diagnose, treat and prevent diseases in cattle, as well as process and analyze disease data. It improves the health of the herd and the efficiency of veterinary work.

Production models of knowledge representation use rules, known as productions, that describe conditions and actions based on the knowledge of experts. These models are a convenient way to describe and formalize the knowledge and rules used in expert systems for decision making. The production model allows the system to apply rules based on facts and conditions and draw conclusions or provide recommendations.

The theory of fuzzy compositional inference is based on fuzzy logic and provides tools for working with fuzzy or uncertain data. Veterinary data can contain varying degrees of certainty or uncertainty, and the use of fuzzy compositional inference allows the system to work with such data and make decisions in the face of uncertainty.

The software tool was created on the basis of a fuzzy model for predicting the causes of diseases, developmental characteristics, the likelihood of clinical symptoms in cattle, using fuzzy set theory, fuzzy rule derivation algorithms. With this software tool, the veterinarian will be able to make predictions based on the results of experimental trials.

Modern computing technologies make it possible to efficiently process and analyze data using production models, fuzzy logic and one-dimensional tables. Such methods provide high flexibility and accuracy in processing cattle disease data and making decisions based on existing knowledge and data.

However, it should be noted that there are other methods and approaches in the field of developing expert systems and data analysis, and the choice of specific methods depends on the specific requirements and context of the task. It is important to take into account the features and limitations of a particular system and choose the approaches that best meet the goals and requirements.

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