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ДОКЛАДЫ

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РЕСПУБЛИКИ КАЗАХСТАН

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EXPERT SYSTEMS KNOWLEDGE BASES FOR SOLVING VETERINARY PROBLEMS

Abstract. Undoubtedly, the factor leading to the death of cattle is the spread of diseases that can worsen the health of animals. Diagnosing animal diseases is difficult if a qualified veterinary professional is not available, which is usually due to the remoteness of livestock farms from scientific veterinary centres. Thus, the use of expert systems for solving veterinary medicine problems is proposed as a solution. An expert system for diagnosing animal diseases is required to simplify the work of veterinarians and subsequently reduce the incidence of animal diseases.The consequence is that the need to implement decision support tools is undeniable, as veterinary medicine is a science that involves possible diagnostic errors, decision-making complexity and an extensive knowledge base. As a result, the use of cognitive maps, the functionality of which is described in this article, is proposed. The development of these decision support tools includes both discrete analytical information and intuitive elements that optimise their impact on everyday veterinary practice. Cognitive maps are active knowledge resources that use animal data to generate case-specific recommendations to support diagnostic decision-making. The knowledge sources used and the process of obtaining, analyzing and evaluating knowledge are described in detail. Productive rules are used as a tool to represent knowledge, which is also used to address the uncertainties that arise in the decision-making process. Introducing one-dimensional tables when structuring a knowledge library is an appropriate solution for system design. Creating a knowledge base in the way described can solve the initial goals of developing a software product for veterinary applications.

Key words: expert system, veterinary medicine, cognitive maps, diagnostics of diseases, database.

Introduction. The course of diagnosis is one of the major decision-making tasks in veterinary medicine. Undoubtedly, establishing a correct diagnosis is a time-consuming task: a specialist is expected to work on analyzing the information and processing it accordingly, as well as qualitatively processing it to create hypotheses about an individual case and the subsequent studies needed to evaluate them. We could describe the process of making a diagnosis using a simple diagram (see Fig. 1). This significant topic has been extensively researched, but relatively little is generally known about the clear mechanisms of the course of animal diagnosis, in both correct and incorrect diagnoses [1,2]. Given the difficulties of the diagnostic process, the use of decision-making support tools (or decision support tools) in routine veterinary practice can increase diagnostic accuracy and reduce the chance of error. The concept of decision-making support is a dynamic source of knowledge that applies information about the animals under study to make recommendations for certain cases [3].

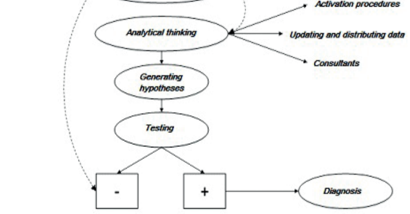

Figure 1 - The process of making a diagnosis

Authors such as, K. Stanovich, G. Norman, in their works, described how specialists usually apply subconscious, intuitive, artificial thinking [4,5]. In this case, a qualified veterinarian will be an exceptionally rational decision maker, able to be guided by step-by-step algorithms for sure. If errors appear in this process, it would indicate the occurrence of heuristics and/or incorrect operations due to improper training or human factors such as a bad mood, stress or distractions such as noisy environment, etc. Most decision aid systems are based on the idea that veterinarians need assistance in improving their analytical thinking by encouraging users to abandon intuition in favor of procedural reasoning. Unfortunately, this conceptual framework limits the practical application of decision-making support systems because most veterinarians, who are exceptionally experienced, often rely on intuitive reasoning.

However, some researchers have focused on the significant role of intuition in making good medical decisions [6,7]. For example, Gabbay and Le May described how experienced clinicians develop strategies based on the use of certain hints to make important decisions quickly without a cumulative information base about specific diagnostic cases [8]. They called these strategies “mindlines”. The cognitive-balanced model emphasizes the need for the veterinarian to develop both intuitive and analytical skills, as well as the unconditional suitability from the use of a decision aid system that helps veterinarians discover a sure balance in each clear case by adapting the manner of thinking to the true conditions of the problem. Practicing veterinarians must learn to trust their intuition, but also know how to prevent unavoidable errors involving heuristics.

The need to adjust to this dynamic balance and the natural occurrence of uncertainty in most medical conditions requires decision aid resources that can handle this complexity, such as cognitive map (CM)-based decision-making [9].

To construct CMs, veterinarians are not required to numerically assess the significance of providing information; they only need an intuitive awareness of the medical scenario and certain factors that need to be considered. As all sorts of experiential studies have shown, CMs can enhance the diagnostic process by connecting a cognitive-balanced solution [10]. A huge superiority of this approach is that it provides the opportunity to incorporate heuristics and intuitive information into the conceptual schema posed [11]. This includes both analytical and synthetic components, often framed as divergent concepts in the course of decision-making, but absolutely integrated into a balanced CM model.

Methods and materials. The mathematical apparatus and apparatus of fuzzy compositional inference theory have been used in the construction of fuzzy set theory and fuzzy logic. The mathematical theory of fuzzy sets and fuzzy logic are generalizations of classical set theory and classical formal logic.

Statistical methods, on the other hand, have been used as statistical expert information processing systems in the general theory of automated systems.

Systematic, analytical and logical analyses have been used in the processing of expert weakly structured data.

The comparison method has been applied when comparing existing intelligent systems in the veterinary medicine field and in processing the experimental data obtained.

The knowledge source determines to some extent the accuracy, reliability, practicality and efficiency of knowledge acquisition. Considering the vast amount of knowledge needed to create an expert system for animal disease diagnosis, 4 main areas have been selected: books, subject matter experts, other materials, literature and information from the internet.

Results and discussion. Cognitive maps are a graph simulating a complex system consisting of nodes (C_i) and relationships (e_{ij}) between concepts, expressing causal relationships between them.

General formula expressing the significance of each concept C_i appears to be one in which the significance of any concept C_i is calculated through calculations of the effects of other concepts on a particular concept with the support of calculation rules expressed by the equation:

$$x_i = f\left(\sum_{\substack{j=1 \\ j\neq i}}^{n} x_j(t-1)w_{ij}\right), \qquad (1)$$

where x_i (t) is the value of the concept C_i at time t; x_j (t - 1) represents the value of the concept C_j at time t - 1; w_{ji} is the weight of the connection between C_j and C_i; f represents a sigmoid function:

$$f = \frac{1}{1+e^{-\lambda x}} \qquad (2)$$

The weights w_{ji} characterize the interconnections. They describe the level of causality between two concepts and can have values in the interval [-1, 1]. The weight symbol indicates a positive causal relationship, that is, an increase in the value of concept C_i initiates an increase in the value of concept C_j or a negative causal relationship. In this final case, an increase in the value of the concept C_i will cause a decrease in the value of C_j or a decrease in C_i will initiate an increase in C_j. If the weight is zero, there is no relationship between the two judgments. Thus, the effect of weight w_{ji} reflects the degree of influence between concepts C_i and C_j.

To model the two-way exposure of S1 and S2 (intuitive and analytic thinking), these connections are described by Equations 1 and 2, introducing the transformation of weights w_{ji} as follows. The team of specialists is asked to analyze all the individual concepts, attributes, relationships, and conditional weights that represent a graphical description of the provided medical scenario (linked graph). Subsequently, the specialists are asked to formulate two parameters: one formulated based on their experience and intuition (S1) and the other based on objective data and precedent-based analysis (S2). The new weights w'_{ji} in formulas 1 and 2 will be obtained through summing the weights validated by experts, namely S1 and S2, consistent with the two systems of thought: $w'_{ij} = S1 + S2$..

$$x_i(t) = f\Big(\sum_{\substack{j=1 \\ j\neq i}}^{n} x_j(t-1) w_{ij}\Big) \quad (3)$$

$$x_i(t) = f\Big[k_1 \sum_{\substack{j=1 \\ j\neq i}}^{n} x_j(t-1) w_{ij} + k_2 x_i(t-1)\Big] \quad (4)$$

We chose summation because it is an elementary calculation that preserves the value of the weights in the formulas, both as related to direction (positive or negative influence) and magnitude. All sorts of CM acquired in consequence of the work of the team of experts will be evaluated by the automatic system, comparing the results with the expected ones.

To illustrate how the model works, a simplified but realistic model of differential diagnosis between such contagious diseases of cattle as anthrax and foot-and-mouth disease is proposed. The differentiation of the two diseases is often nontrivial, since the symptomatology of both anthrax and foot-and-mouth disease is extremely variable. The complexity of this task suits our purpose because CMs are especially useful in controversial contexts and when incomplete or incorrect information must be used. Fig. 2 presents a simple model of the problem: the clouds focus on the decision-making concepts, that is, the two diagnoses we are considering; the ellipses outline the mainly significant moments (factor-concepts) involved in distinguishing the two possibilities, the inputs of our CM.

In order to differentiate between the two diseases in amzbiguous variants, all clearly articulated subsequent characteristics of the presented diseases should be taken into account. All of this information must be combined to suggest a final conclusion, because each independent source of information may almost equally suggest either foot-and-mouth disease or anthrax.

Following the simpler CM model, only clinical data are used to aid in the decision-making process. To illustrate this process, experienced veterinarians have considered the likelihood of differentiating anthrax from foot-and-mouth disease based on their experience. The source of the information is based on the experiences of veterinarians.

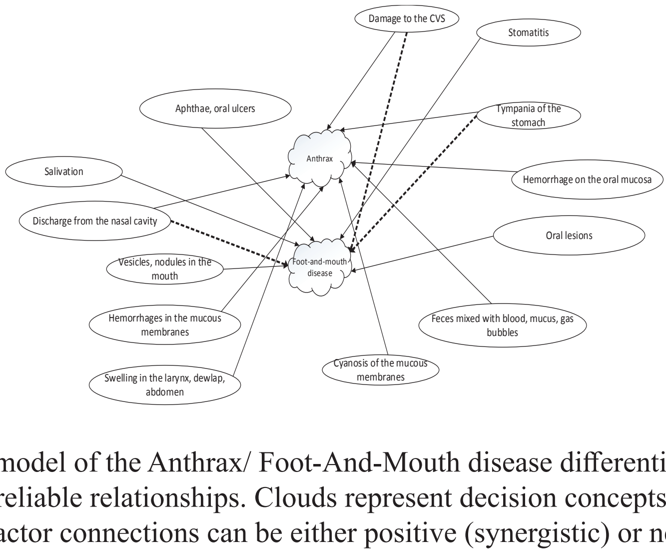

Figure 2 - Simplified model of the Anthrax/ Foot-And-Mouth disease differentiation problem. Dotted lines indicate weak or unreliable relationships. Clouds represent decision concepts and ellipses represent factor concepts. Factor-factor connections can be either positive (synergistic) or negative (competitive).

Attributes	Anthrax	Foot-and-mouth disease
Salivation	0	high
Stomatitis	0	high
Hemorrhage on the oral mucosa	high	0
Oral lesions	0	high
Aphthae, oral ulcers	0	high
Vesicles, nodules in the mouth	0	high
Tympania of the stomach	high	low
Feces mixed with blood, mucus, gas bubbles	high	0
Discharge from the nasal cavity	high	low
Swelling in the larynx, dewlap, abdomen	high	0
Defeat of the CVS	high	low
Cyanosis of the mucous membranes	high	0
Hemorrhages in the mucous membranes	high	0

Table 1 - Table of differentiation of diseases

The following simple rules were used to sum the associated weights: 0 + any value = 0; Low + Low = Low; Low + Medium = Medium; High + Low = High; Very high + low = medium; Medium + Medium = Medium; Medium + High = High; Medium + Very High = High; High + High = High; Very High + Very High = Very High.

The resulting values need to be treated as random and can be modified to fit specific contexts and/or the degree of belief of the veterinarian in models based on experience or evidence. This means that practitioners who choose to use this decision aid mechanism can adapt it to their decision-making style by making appropriate adjustments to the weighting rules.

A balanced weighting operation was performed on each attribute based on the veterinarians' experience (see Table 1). The values can be summed to include the final weight of the simple syntax, then the two values are summed, obtaining the final weight of each attribute in the CM software.

The above Table 1 is used to populate the CM model, determining the relative importance of each of the m factor concepts in relation to the n probable decision-making concepts. These weights will be translated into numerical weights using the algorithm used. For example, a very high corresponds to 90% of the relevance of a given factor, and the assigned weight will be 0.9. Consequently, the CM algorithm will act with two matrices, W and X. Matrix W covers all connection weights and may include negative values if there are competing relationships between factors, while X covers values assigned in a particular case. To place values in X, the decision maker will assign values to each attribute present in the CM model using the same degrees (0, low, medium, high, or very high). Obviously, only truly available data will be placed in X, while the input factor will correspond to nodes that are not activated (0 values). For example, in this case, a veterinarian might use the CM decision tool using only body temperature, and skin condition, assigning high, medium, and low degrees and 0 to all other factor models, respectively (the model will then suggest an ES (expert system) diagnosis).

Diagnosis is a problem solving based on a static database (fact base) of initial factors. e.g. age of the animal, sex, course of the disease, medical history, etc. As these factors play different roles in the diagnosis of disease, it must be decided which factors should be chosen as the basis for the diagnosis of disease. If too many elements are chosen, it weakens those factors that are really important in diagnosing the disease; if too few are chosen, some important factors are missed. Thus, the choice of symptoms is largely up to the experts. Thus, the symptoms and information relevant to the diagnosis of disease provided by the experts have been divided into several levels.

According to different levels of knowledge and connections between knowledge, the fact base can be divided into tables with a certain logical causal relationship.

Knowledge in the field of animal disease diagnosis has its own unique properties. While traditional methods of knowledge representation for handling animal disease diagnostic information simply use a very large number of rules, it does not take into account the fact that disease symptoms and associated information are generally not segregated into specific disease categories. This means that many diseases have common or similar symptoms, so it is difficult to have a very clear and structured expression of the relationship between these diseases and symptoms when writing rules.

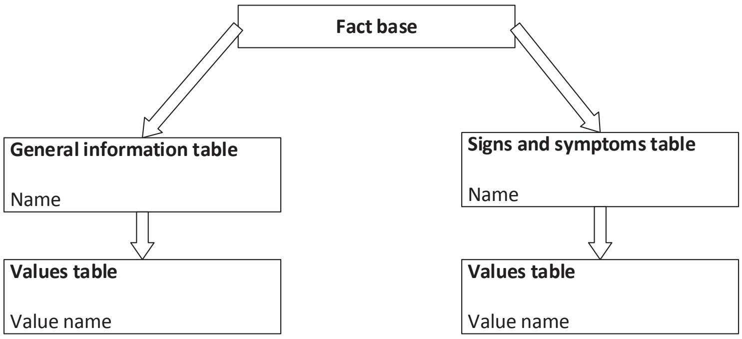

Figure 3- Relationship between fact database tables

People have become accustomed to putting information about an object into a single record when processing information, whereas the brain puts information about an object into different ‘records’ when storing information. This way of storage can be well modelled using a one-dimensional database [19]. A rule library created using a one-dimensional database can not only satisfy the different knowledge requirements of disease diagnosis, but also simulate the input and output of the brain during reasoning. Thus, the rule base structure of the expert system for animal disease diagnosis is as follows:

Table 2 – One-dimensional database

Rule_name	**Premise** (symptoms)	**Action** Conclusion (illness)	**w**	**Active**

The weighting factor of a symptom (w) can be determined by the expert based on its importance. Diseases and symptoms can be sorted according to a tree structure. After sorting, relevant symptoms can be found by disease name as well as other information relating to the disease. In the library, the total weighting factor for each disease is 100%.

The data structure of this simulation rule library is very simple, but its function is powerful. The expert system created in this way is based on a request in the process of diagnosing a disease, using only a few judgments, and does not require writing a large number of rules, and the time period for creating a knowledge base is short. In addition, there is no need to change the entire system to change knowledge in the knowledge base, so the output mechanism can exist as a separate module.

Facts are at times somewhat ambiguous - (the meaning of the facts is unclear or ambiguous and must be determined by the context), incomplete (e.g. no complete information can be obtained), inaccurate (the actual observation result differs from the actual situation), random, ambiguous, etc. The uncertainty of facts is usually expressed by a weighting factor, and the range of its values is:

$$0 \ll \omega \ll 1, \text{или } 0 \ll \omega \ll 100\% \quad (5)$$

Uncertainty rules reflect patterns of objective things. In solving practical problems, the knowledge possessed by experts is empirical rather than precise. Exact knowledge is mainly formulas, axioms, laws, theorems, etc. When empirical knowledge is expressed in the form of rules, the rules are uncertain [20]. The uncertainty of rules can also be expressed by weighting values.

For example, IF cough, THEN pneumonia w = 0.2;

Indicates that when an animal is coughing, the chance that the animal has pneumonia is 0.2 (20%). The formula for calculating the reliability of the diagnosis when the elements of the symptoms are linked by the «AND» operator:

$$IF\ E_1 \wedge E_2 \wedge \dots \wedge\ E_n\ THEN\ H\ \ \omega(R) \quad (6)$$

The reliability of the diagnosis H is:

$$\omega(H) = \omega(R) * MIN\{\omega(E_1), \omega(E_2), \dots \omega(E_n)\} \quad (7)$$

This formula reflects the fact that the reliability of the diagnosis H is the reliability of the rule w (R) and the reliability of the preamble. - preamble value;

The formula for calculating the reliability of the conclusion when the symptoms are associated with the «OR» operator:

$$IF\ E_1 \vee E_2 \vee \dots \vee E_n\ THEN\ H\ \ \omega(R) \quad (8)$$

$$\omega(H) = \omega(R) * MIN\{\omega(E_1), \omega(E_2), \dots \omega(E_n)\} (9)$$

After entering the initial data, the system will search for the disease that best matches. To achieve this, the system will first search for a disease that can explain all of the input symptoms. If such a disease is not in the database, the system will search for a disease that can explain one less symptom, and so on, until a possible disease is found. In this process, a hypothetical conclusion is actually made. In this process, a hypothetical conclusion is actually drawn. After further investigation and testing, the hypothesis is rejected or accepted. If the hypothesis is not found based on the current set of input symptoms, another hypothesis will be found based on the next new set of symptoms. For example, if there are 3 input symptoms S1, S2 and S3, the hypothesized disease will be searched based on the following set of symptoms: {S1, S2, S3}, {S1, S2}, {S1, S3}, {S2, S3}. If all symptom sets have been tested and the hypothetical conclusion is not reached, the reasoning process is aborted (unsuccessful reasoning).

When diagnosing animal diseases, it is common that the input set of symptoms is explained by multiple diseases, and the importance of the symptoms in these sets of symptoms is different for each disease, which means that the validity of these hypotheses is different. Therefore, in accordance with the expression of the production rules that we used: «IF ..., THEN ...», the values of the weighting factors of each disease are added so that the probability of hypothetical conclusions drawn from the same set of symptoms is different.

For example, if the conditions of the input data are: cough, nasal discharge, wet wheezing, fever.

From the above conditions, the following diseases can be found in the knowledge base as hypothetical conclusions: bronchial pneumonia; lobar pneumonia. Then, if they are written in the form of rules:

IF cough AND nasal discharge AND moist wheezing in the lungs AND fever, THEN bronchial pneumonia;

IF cough AND nasal discharge AND wet wheezing in the lungs AND fever, THEN croupous pneumonia.

According to our proposed method of representing knowledge and the method of creating a knowledge base, the above knowledge can be expressed in the form of table 3.

Table 3 - An example of the knowledge base of the expert system for the diagnosis of animal diseases

Rule_ID	Premise	Action	w	Active
1	Cough	Bronchial pneumonia	0,08	1
2	Discharge from the nose	Bronchial pneumonia	0,07	1
3	Moist wheezing in the lungs	Bronchial pneumonia	0,1	1
4	Cough	Croupous pneumonia	0,15	1
5	Discharge from the nose	Croupous pneumonia	0,06	1
6	Moist wheezing in the lungs	Croupous pneumonia	0,2	1

Creating a knowledge base in the way described above can solve the following problems in the process of entering symptoms during the diagnosis of disease: 1) All information selected by the user is provided by the system, and there is no problem that the information entered does not match, 2) in the rule base we have assumed that each part of the input information corresponds to at least one rule, that is, there must be one or more diseases with information entered by the user as a diagnostic condition, 3) when several diseases are selected, their active states differ.

Conclusion. We affirm that cognitive maps, already generally recognized and validated in the field of medical diagnosis, have not gained appropriate attention from scientists and veterinary physicians. It is likely that in the near future, more CM-based decision-making tools will become available both during veterinary training and in everyday medical practice, providing a better balance of analytical and synthetic processes with beneficial effects on decision setting and outcomes. The property of cognitive maps allows us to visualize levels of causality between concepts, and their graphical device allows us to freely consider the connections between concepts. In addition, we affirm that teaching veterinarians to balance intuitive and analytical thinking will allow them to - increase their cognitive awareness of how they reason, solve problems, and pay attention to the consequences of making decisions, both positive and negative. In this way, veterinarians will strengthen their ability to learn by doing, forming a freely adaptable experience that is extremely useful in environments of high difficulty or rapidly changing data.

In general, the knowledge base tools mentioned above have proved their effectiveness in developing an expert system for veterinary tasks. To date, 11 algorithms for the prevention and eradication of contagious diseases such as anthrax, vesicular stomatitis, colibacillosis, rickettsiosis, foot and mouth disease, salmonellosis, tuberculosis, brucellosis, rabies, pasteurellosis and trichophytosis have been developed and entered into the database. The database stores the knowledge in the subject area that is essential for a diagnosis, including age, breed, symptoms, photographs and other important information. In total, the database includes 251 veterinary medicinal products, including 61 preparations used for surgical diseases, 75 preparations used for obstetrical diseases, 72 vaccines and sera against infectious diseases, and 43 preparations against parasites and 34 veterinary facilities.

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ВЕТЕРИНАРИЯ МІНДЕТТЕРІН ШЕШУГЕ АРНАЛҒАН САРАПТАМАЛЫҚ ЖҮЙЕЛЕРДІҢ БІЛІМ ҚОРЫ

Аннотация. Малдың өліміне әкелетін фактор - бұл жануарлардың денсаулығын нашарлататын аурулардың таралуы. Егер ветеринария саласында білікті маман болмаса, жануарлар мен мал ауруларын диагностикалау қиынға соғады, бұл әдетте мал шаруашылығының ғылыми ветеринарлық орталықтардан қашық болуымен байланысты. Осылайша, ветеринария міндеттерін шешу үшін сараптамалық жүйелерді пайдалану шешім ретінде ұсынылады. Мал мен жануарлар ауруларын диагностикалаудың сараптамалық жүйесі ветеринарлардың жұмысын жеңілдету және кейіннен жануарлардың ауруын азайту үшін қажет. Соның салдарынан, шешім қабылдауды қолдау құралдарын енгізу қажеттілігі күмән тудырмайды, өйткені ветеринария - бұл мүмкін диагностикалық қателіктер, шешім қабылдаудың қиындығы және кең білім қоры бар ғылым. Нәтижесінде, функционалы осы мақалада сипатталған танымдық карталарды пайдалану ұсынылады. Бұл шешімдерді қолдау құралдарын әзірлеу дискретті талдау ақпаратын да, олардың күнделікті ветеринарлық тәжірибеге ықпалын оңтайландыратын интуитивті элементтерді де қамтиды. Когнитивтік карталар-бұл диагностикалық шешімдер қабылдауды қолдау үшін нақты жағдайлар бойынша ұсыныстар жасау үшін жануарлар туралы мәліметтерді пайдаланатын белсенді білім ресурстары.Қолданылатын білім көздері және білімді алу, талдау және бағалау үрдісі егжей-тегжейлі сипатталған. Өнімділік ережелері білім беру құралы ретінде қолданылады, сондай-ақ шешім қабылдау барысында туындайтын белгісіздік мәселелерін шешу үшін де қолданылады. Білім кітапханасын құрылымдау кезінде бір өлшемді кестелерді енгізу жүйені жобалау кезінде қолайлы шешім болып табылады. Сипатталған тәсілмен білім қорын құру ветеринария мәселелерін шешу үшін бағдарламалық өнімді әзірлеу кезінде бастапқыда қойылған мақсаттарды шеше алады.

Түйін сөздер: сараптамалық жүйе, ветеринария, когнитивтік карталар, ауруларды диагностикалау, деректер қоры.

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БАЗЫ ЗНАНИЙ ЭКСПЕРТНЫХ СИСТЕМ ДЛЯ РЕШЕНИЯ ЗАДАЧ ВЕТЕРИНАРИИ

Аннотация. Несомненно, фактором, приводящим к гибели скота, является распространение болезней, которые могут ухудшить здоровье животных. Диагностика болезней животных испытывает трудности, если нет квалифицированного специалиста в области ветеринарии, что обычно связано с удаленностью животноводческих хозяйств от научных ветеринарных центров. Таким образом, в качестве решения предлагается использовать экспертные системы для решения задач ветеринарии. Экспертная система диагностики болезней животных необходима для упрощения работы ветеринаров и последующего снижения заболеваемости животных. Как следствие, необходимость внедрения инструментов поддержки принятия решений не вызывает сомнений, поскольку ветеринария – это наука, которая включает в себя возможные диагностические ошибки, сложность принятия решений и обширную базу знаний. В результате предлагается использование когнитивных карт, функционал которых описан в данной статье. Разработка этих инструментов поддержки принятия решений включает как дискретную аналитическую информацию, так и интуитивно понятные элементы, которые оптимизируют их влияние на повседневную ветеринарную практику. Когнитивные карты – это активные ресурсы знаний, которые используют данные о животных для выработки рекомендаций по конкретным случаям для поддержки принятия диагностических решений.Подробным образом описаны использующиеся источники знаний и процесс получения, анализа и оценки знаний. Продукционные правила используется как инструмент представления знаний, которые так же используется для решения проблем возникающих неопределенностей в процессе принятия решений. Внедрение одномерных таблиц при структурировании библиотеки знаний является подходящим решением при проектировании системы. Создание базы знаний описанным способом может решить изначально поставленные цели при разработке программного продукта для решения задач ветеринарии.

Ключевые слова: экспертная система, ветеринария, когнитивные карты, диагностика заболеваний, база данных.

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