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Building a Fuzzy Sugeno Model for Diagnosing Cattle Diseases on the Basis of Developing a Knowledge Base

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Abstract. The main goal of the study is to build a fuzzy Sugeno model for diagnosing diseases in cattle based on the development of a knowledge base. To achieve this goal, an analytical review of mathematical methods for assessing the state of animals, soft computing methods for solving classification problems was carried out. The scientific novelty of the research is the improvement of the algorithm for constructing a Sugeno fuzzy model based on the development of a knowledge base for diagnosing diseases in cattle and solving classification problems based on the theory of fuzzy sets and interval methods, as well as developing improved algorithms and building models for diagnosing diseases in cattle based on Sugeno's fuzzy inference. When constructing a Sugeno fuzzy logical model for diagnosing diseases in cattle, the optimal number of rules and, accordingly, the values of their membership functions were found. Membership function parameters were obtained from experts in the veterinary field. In the future, the parameters of the membership function were tuned using neural networks and evolutionary algorithms to obtain the minimum number of fuzzy rules. The tasks of assessing, classifying and diagnosing a disease in cattle are solved based on training in seventeen signs. Types of diseases are diagnosed, such as ketosis, osteodystrophy, secondary osteodystrophy and hypomicroelementosis, which must be recognized. Based on the proposed approach, a program for diagnosing diseases in cattle has been developed. On the basis of the developed program, practical problems are solved that provide data training with the creation of a model and visualization of the results obtained and the reliability and accuracy in diagnosing at all stages of using the program. The ease of use of the software package lies in the fact that it does not require the user to have in-depth knowledge of its structure and the operating system of the computer.

INTRODUCTION

In the world based on mathematical modeling that supports fuzzy logic in fuzzy sets, in particular, in neutrosophic fuzzy sets, research is being carried out aimed at improving, developing and creating computer diagnostic systems in order to identify types of diseases and their causes at an early stage, and improving veterinary treatment methods. In this regard, building models for diagnosing animal diseases based on fuzzy logic and neutrosophic fuzzy sets, developing algorithms and programs for predicting and diagnosing diseases in cattle is one of the important tasks.

In our republic, special attention is paid to the introduction of information and communication technologies in veterinary medicine and all branches of animal husbandry, the coordination of breeding work, as well as the development and implementation of targeted state programs in these areas.

L.A.Zade, E.Kh. Mamdani, M. Sugeno, Y. Tsukamoto developed fuzzy inference models. V. I. Junkerov, K. A. Laishev, G. Rodrigo, L. Ferreira, T. Ya. Fuzzy inference algorithms differ mainly in the variety of rules used, the type of logical operations and defuzzification methods [1-3].

The aim of the study is to develop models and algorithms for diagnosing diseases in cattle based on Sugeno's fuzzy inference and neutrosophic fuzzy sets.

The objectives of the study are following:

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- Conducting an analytical review of mathematical methods for assessing the state of animals, methods of soft calculations, as well as the use of neutrosophic sets for solving classification problems;
- Improving the algorithm for constructing a fuzzy Sugeno model, based on the development of a knowledge base, for diagnosing diseases in cattle;
- Improvement of the algorithm for solving classification problems based on the theory of Neutrosophic fuzzy sets and interval methods;
- Development of improved algorithms and construction of models for diagnosing diseases in cattle based on neutrosophic sets and Sugeno's fuzzy inference;

Today, numerous studies are being carried out on the prevention and treatment of animal diseases in important areas:

- The development of a method for the rapid diagnosis of mixed bacterial diseases of farm animals;
- Creation of a local biological product for the combined treatment of ketosis, hypomicroelementosis, osteodystrophy and secondary osteodystrophy in cattle;
- Development of local vaccine preparations for the simultaneous prevention of mixed bacterial diseases.

Most scientists [4] devoted their research to the study of ketosis, alimentary and secondary osteodystrophy, impaired vitamin and mineral metabolism, however, when studying the etiology, mechanism of development, diagnosis of methods of prevention and treatment, osteodystrophy, secondary osteodystrophy, the authors came to various conflicting conclusions.

It was revealed that the characteristic courses of secondary osteodystrophy in cattle is accompanied by a decrease in the number of erythrocytes and hemoglobin in the blood, an increase in the acidity of the contents and a decrease in the amount and activity of the rumen microflora.

Although the literature on the prevalence, causes, developmental features, clinical signs, diagnosis, treatment and measures of group prevention of secondary osteodystrophy, osteodystrophy, microelementosis, ketosis in cattle is sufficient, for these listed factors in black-and-white cows raised abroad, under conditions of new farms in the country, diseases associated with metabolic disorders are conditionally divided into the following groups:

- Violation of carbohydrate-fat and protein metabolism.
- Violation of mineral metabolism (alimentary, enzootic and secondary osteodystrophy).
- Diseases caused by deficiency or excess of micronutrients (hypocobaltosis, hypocuprosis, caries, fluorosis, deficiency of zinc and manganese, excess of barium, molybdenum and selenium).
- Diseases (hypo and avitaminosis) mainly mainly with predominant disorders of vitamin metabolism [5]. Lack of protein, calcium, iron, carotene and trace elements (iodine, cobalt, copper, zinc) in the diet of cows in winter, low ratio of sugar and protein (0.32: 0.4: 1), lack of active mats, secreted protein, causes disorders vitamin and mineral metabolism [6, 7].

MATERIALS AND METHODS

When constructing a mathematical model, researchers often face the problem of developing models of complex processes characterized by various types of uncertainties. In such cases, they have to choose one of two things: either to consider the influence of uncertainties as insignificant, which led to a loss of information and a decrease in the adequacy of the model to the real process, or to complicate the mathematical models. In practice, one often has to deal with data that is inconsistent with the assumptions underlying the classical methods.

Components of soft computing can be applied independently, for example, as in fuzzy computing, neural computing, evolutionary computing.

In the process of research, problems arise in solving model problems in the field of veterinary medicine and in solving real life problems, as well as diagnosing based on expert veterinary data. The solution of problems of intellectual analysis is characterized by the insufficiency of numerical calculations and the incompleteness of important information about the conditions of the problem.

To build a model for diagnosing diseases in cattle, a sample was received from experts (X_r, y_r), $r=\overline{1,M}$, where $X_r=(x_{r,1}, x_{r,2}, ..., x_{r,n})$ - input vector *r* - couples and y_r - corresponding output vector.

Our task is to build a fuzzy model as follows:

$$\bigcup_{p=1}^{k_j}\left(\bigcap_{i=1}^{n} x_i = a_{i,jp} - w_{jp} \quad \text{with weight}\right) \rightarrow y_j = b_{j,0} + b_{j,1}x_1 + \ldots + b_{j,n}x_n + \\ + b_{j,n+1}x_1^2 + \ldots + b_{j,2n}x_n^2 + \ldots + b_{j,n+l-1}x_1^l + \ldots + b_{j,ln}x_n^l. \tag{1}$$

When constructing this model, if l=0, the case is considered as a singleton form model [8, 9]. A linear model in the Sugeno representation, consisting of derivations of fuzzy rules in the case l=1, was studied in [10, 11]. The case with l=2 was considered in [12].

In the process of building a model, it is necessary to find the values of the coefficients of the fuzzy inference rule as follows:

$$B = (b_{1,0}, b_{2,0}, ..., b_{m,0}, b_{1,1}, b_{2,1}, ..., b_{m,1}, ..., b_{1,n} b_{2,n}, ..., b_{m,n}, ..., b_{1,ln} b_{2,ln}, ..., b_{m,ln}), \\ i=\overline{1,n},\ j=\overline{1,m} \tag{2}$$

And minimize the following function:

$$\sum_{r=\overline{1,M}} \left(y_r - y_r^f\right)^2 \rightarrow \min \tag{3}$$

Where y_r^f - output of input data in *r*- selection line (X_r) in fuzzy knowledge base - b - parameter.

The solution of problem (1) corresponds to the solution of the following equation $Y = A \cdot B$, where:

$$A = \begin{bmatrix} \beta_{1,1}, ..., \beta_{1,m}, \quad x_{1,1} \cdot \beta_{1,1}, ..., x_{1,1}.\beta_{1,m}, \quad ..., \quad x_{1,n} \cdot \\ \cdot \beta_{1,1}, ..., x_{1,n} \cdot \beta_{1,m}, ..., \quad x^l{}_{1,1} \cdot \beta_{1,1}, ..., x^l{}_{1,1}.\beta_{1,m}, \quad ..., \quad x^l{}_{1,n} \cdot \beta_{1,1}, ..., x^l{}_{1,n} \cdot \beta_{1,m} \\ \vdots \\ \beta_{M,1}, ..., \beta_{M,m}, \ x_{M,1} \cdot \beta_{1,1}, ..., x_{M,1} \cdot \beta_{1,m}, \ ..., \ x_{M,n} \cdot \\ \cdot \beta_{M,1}, ..., x_{M,n} \cdot \beta_{M,m}, ..., \quad x^l{}_{M,1} \cdot \beta_{1,1}, ..., x^l{}_{M,1} \cdot \beta_{1,m}, \ ..., \ x^l{}_{M,n} \cdot \beta_{M,1}, ..., x^l{}_{M,n} \cdot \beta_{M,m} \end{bmatrix}, \tag{4}$$

In the discrete case:

$$\beta_{j,r} = \frac{\mu_{f_j}(X_r) \cdot f_j}{\sum_{k=1}^{m} \mu_{f_j}(X_r)} \tag{5}$$

And in a continuous case:

$$\beta_{j,r} = \frac{\mu_f(X_r)\cdot f_j}{\int_{f_-}^{f_+} \mu_f(X_r)df} \tag{6}$$

$$f_j = b_{j,0} + b_{j,1}x_{r,1} + b_{j,2}x_{r,2} + ...+ b_{j,n}x_{r,n} + b_{j,n+1}x_{r,1}^2 + b_{j,n+2}x_{r,2}^2 + ...+ b_{j,2n}x_{r,n}^2 + \\ ....+ b_{j,n+l-1}x_{r,1}^l + b_{j,n+l}x_{r,2}^l + ...+ b_{j,ln}x_{r,n}^l \tag{7}$$

Exit j – regulations, $\mu_{f_j}(x_r)$ - membership functions corresponding to each experimental data for each case:

$$\begin{aligned} \mu_{f_j}(X_r) = {} & \mu_{j,1}(x_{r,1})\cdot\mu_{j,1}(x_{r,2})\cdot\mu_{j,1}(x_{r,3})\cdot.......\cdot\mu_{j,1}(x_{r,ln}) \vee \\ & \vee \mu_{j,2}(x_{r,1})\cdot\mu_{j,2}(x_{r,2})\cdot\mu_{j,2}(x_{r,3})\cdot.......\cdot\mu_{j,2}(x_{r,ln}) \vee \\ & .... \\ & \vee \mu_{j,k_j}(x_{r,1})\cdot\mu_{j,k_j}(x_{r,2})\cdot\mu_{j,k_j}(x_{r,3})\cdot.......\cdot\mu_{j,k_j}(x_{r,ln}), \\ r = \overline{1,n}. \end{aligned} \tag{8}$$

In the process of solving real problems $m(n+1) < M$. In this case, the solution of the system of equations $Y = A\cdot B$ comes down to problem solving $A^T Y = A^T A\cdot B$ [13, 14].

The membership functions of fuzzy terms used in this knowledge base were chosen by an expert.

When constructing a Sugeno fuzzy logical model for diagnosing diseases in cattle, a rational number of rules and effective values of their membership functions were chosen.

Initially, the parameters of the membership function were obtained from experts in the veterinary field. In the future, it is necessary to adjust the parameters of the membership function using neural networks and evolutionary algorithms to obtain the minimum number of fuzzy rules.

RESULTS

The result of a fuzzy rule is represented by fuzzy terms or a linear relationship and depends on what type of model was used - the Mamdani or Sugeno model.

This allows solving several existing (model) classification problems, making an assessment based on the constructed cattle membership function, and comparing processes with the results of several algorithms [15].

The membership functions of the parameters for assessing the state of non-contagious diseases in cattle have been constructed. In this case, the tasks of assessing, classifying and predicting the disease are solved on the basis of 17 signs. According to accepted veterinary clinical practice, the results of the diagnosis of cattle can be classified as follows:

- y_1 - ketosis;
- y_2 - osteodystrophy;
- y_3 - secondary osteodystrophy;

- y_4 - hypomicroelementosis.

The listed types of diseases that need to be recognized are diagnosed. When diagnosing osteodystrophy, ketosis, secondary osteodystrophy, hypomicroelementosis in cattle, the following main parameters are taken into account (possible values are indicated in brackets, including) [16, 17]:

The underlying disease is diagnosed in accordance with accepted veterinary clinical practice. Based on the information provided, a list of diagnoses is compiled and each diagnosis is given a numerical value. When establishing diagnoses of secondary osteodystrophy, ketosis and hypomicroelementosis, we take into account the following main features:

- x_1 - Temperature ^oC;
- x_2 - Pulse, in one minute;
- x_3 - Breathing, in one minute;
- x_4 - Rumination, in two minutes;
- x_5 - Number of erythrocytes mln/mkl;
- x_6 - Hemoglobin, g/l by the method (Sali's Hemometer);
- x_7 - Total protein, g/l (refractometry method);
- x_8 - Total calcium, mmol/l (Vigev Karakashov's method);
- x_9 - Organic phosphorus mmol/l (Pulse method by V.F. Kromyslov, modified by L.A. Kudryatsev);
- x_{10} - Glucose, mmol/l (color reaction with orthotoluidine);
- x_{11} - Reserve alkali (CO_2) about % (by the method of I.P. Kondrakhin);
- x_{12} - Copper mmol/l;
- x_{13} - Cobalt mmol/l;
- x_{14} - Manganese mmol/l;
- x_{15} - Zinc mmol/l;
- x_{16} - Number of ciliates in the rumen 1000/ml;
- x_{17} - The state of cicatricial fluid (Rameter) [4].

The task of diagnostic classification is to compare one of the solutions for each combination of parameter values $y_j (j = \overline{1,4})$.

The program for diagnosing diseases in cattle is developed in the Python programming language version 3.6.7. When processing data, they are loaded from 2 libraries: numpy == 1.20.3 xlrd == 2.0.1.

Experimental studies extract experimental data from the DataFrame (fig. 1). The error that occurs when estimating the parameter is taken into account. Based on the Sugeno fuzzy algorithm, the parameter of the membership function is adjusted. (fig. 1).

The created program for diagnosing diseases in cattle based on the fuzzy Sugeno model (fig. 1) has the following features [18, 19]:

- Solving practical problems using fuzzy algorithms ensures the efficiency of the software package and saves time and money;

- Data training with the creation of a model and visualization of the results obtained in the form of an Excel spreadsheet;
- The ease of use of the software package lies in the fact that it does not require the user to have deep knowledge of its structure and the operating system of the computer;
- The fact that parts of the functional programs of the software package consist of standard elements ensures its uniformity and similarity;
- Provides reliability and accuracy in diagnosing at all stages of using the program.

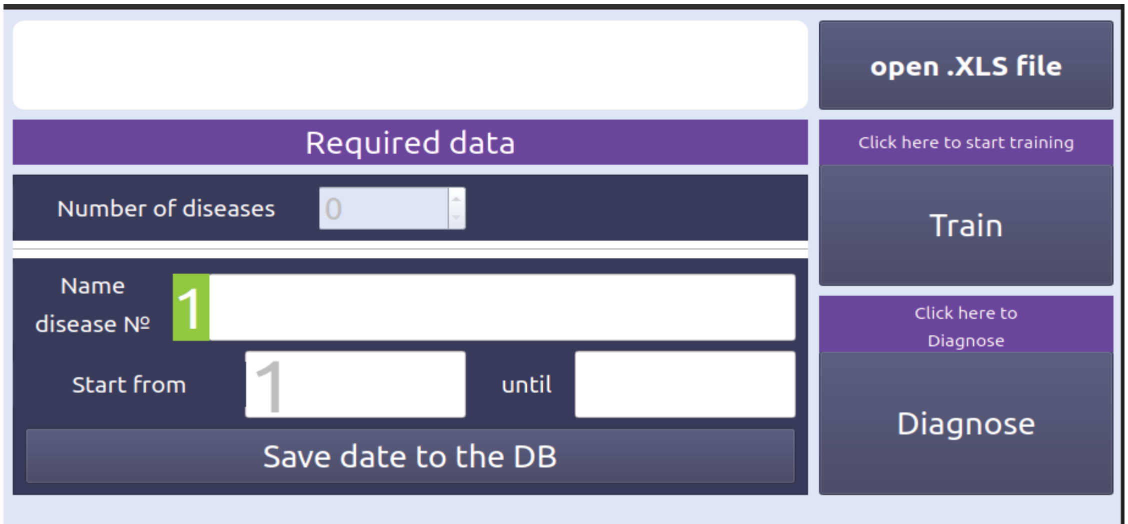

FIGURE 1. General view of the program interface.

Data search. The XLS file is downloaded from the "Download" section using the button. The data must be in Excel format and on the first sheet of Excel is a master of expert data objects, which are therefore separated by disease classes in cattle. Because the program first learns from expert data on bovine diseases and then diagnoses them based on those diseases.

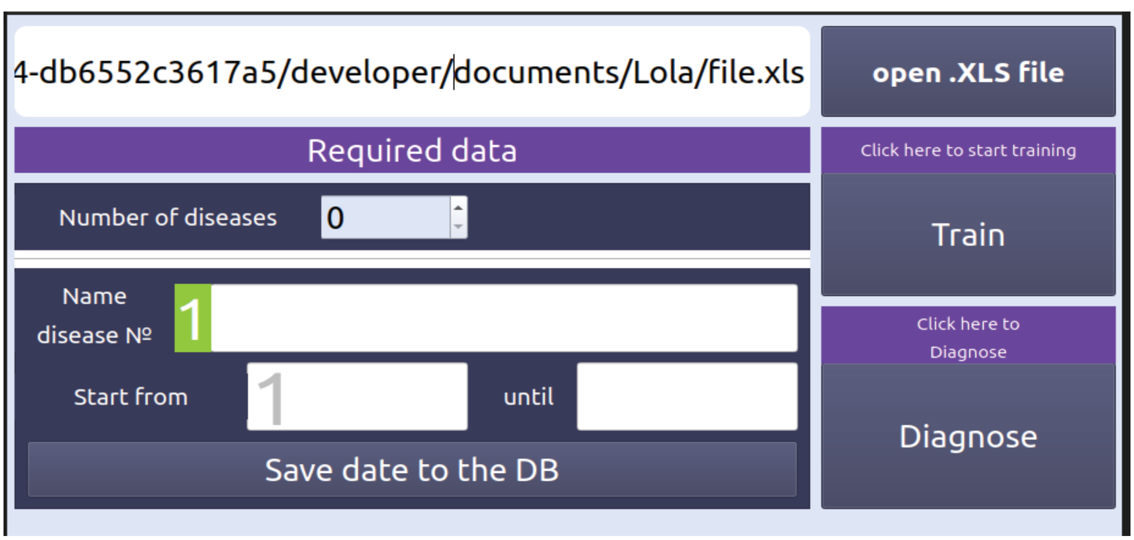

FIGURE 2. Interface for loading data into the program.

The bovine disease diagnosis program is universal for all diseases because the program can diagnose any diseases by being trained with expert data set. The program works for m-number of diseases and n-objects.

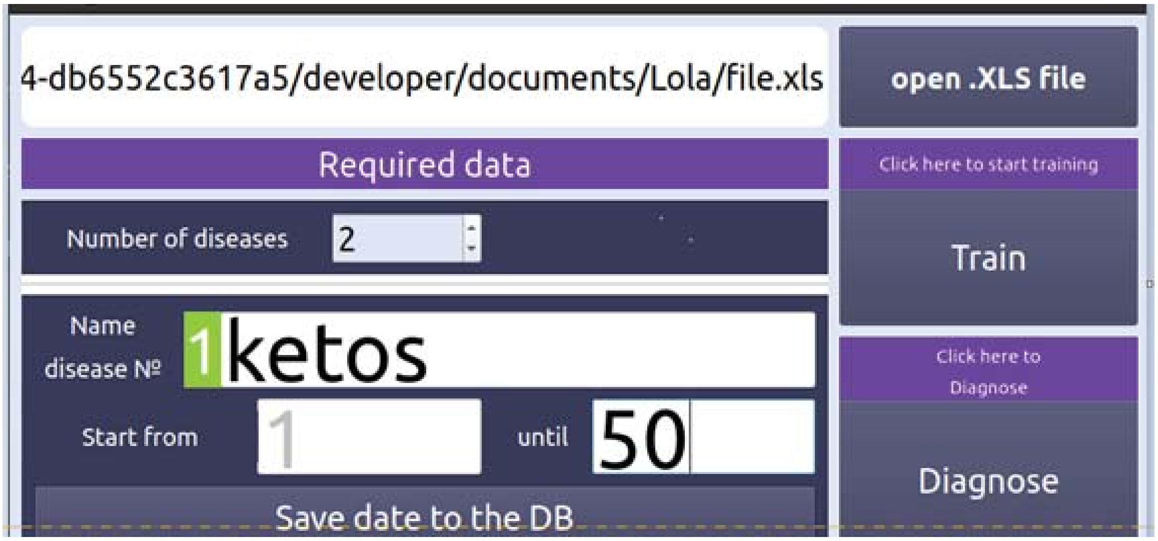

FIGURE 3. The window for entering the number of diseases in the diagnostic mode.

The number of diseases and disease names are entered into the program, the range is indicated, and the teach button is pressed.

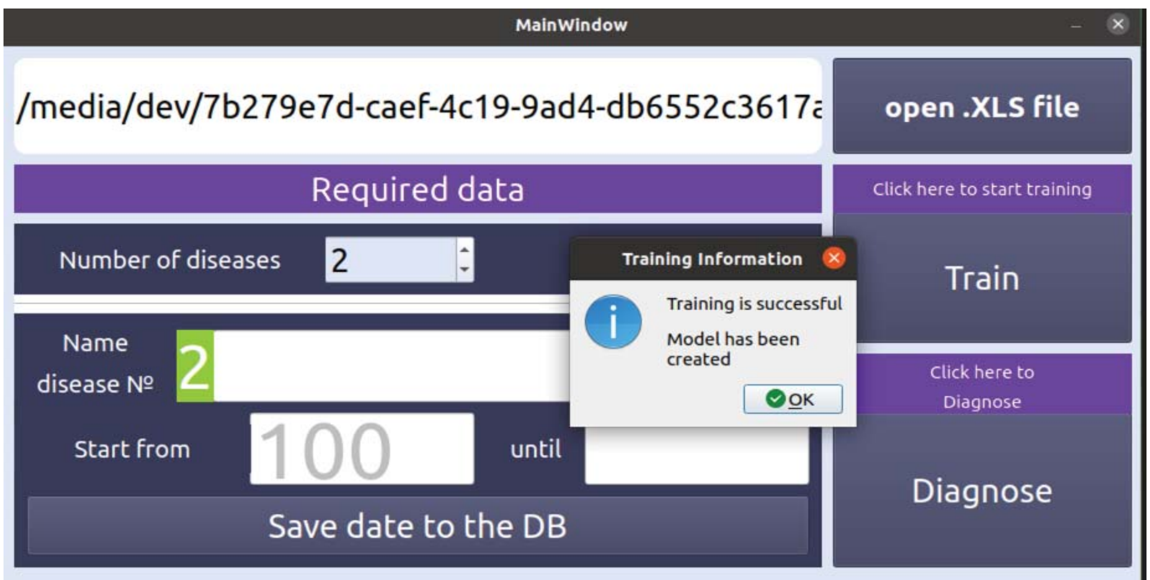

FIGURE 4. Simulation window.

After training and creating a model, the diagnose button is pressed, and when this button is pressed, the program diagnoses the disease in cattle on the excel file.

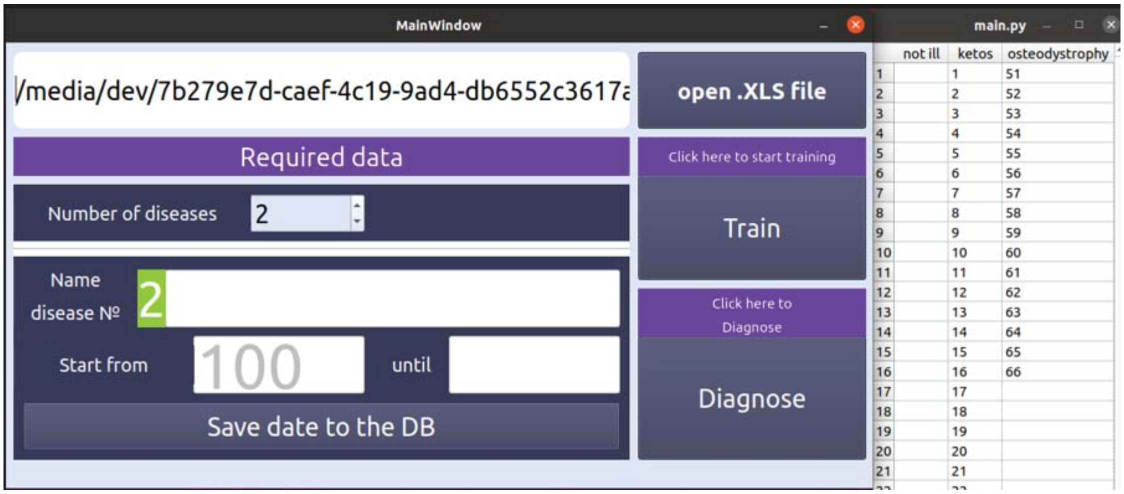

FIGURE 5. The window is in diagnostic mode.

From Figure 5. in the mode of diagnosing a disease in cattle, it can be seen that the program divided objects into classes (diseases) example (1,2, etc. cattle do not get sick, 3,4,6, etc. suffer from ketosis and 14, 15, etc. suffer from osteodystrophy) [20-22].

Let us consider a computational experiment of a program for diagnosing diseases in cattle.

DISCUSSION

In this paper, the construction and presentation of logical-linguistic models in the case of appropriate parameters, allowing to assess the likelihood of primary and secondary osteodystrophy, ketosis, hypomicroelementosis in cattle imported from livestock farms. The Sugeno model of the study is compared with experimental veterinary data conducted in the Samarkand region by veterinarian B. Eshburiev. The predictive models use fuzzy set theory, taking into account the identified 17 signs that contribute to the progression of diseases in cattle, based on statistical reports on the results obtained as a result of several experiments.

Good results have been shown in computer diagnostic systems, to improve the quality of optimal treatment, etc. Uzbekistan has not developed a system for diagnosing diseases in cattle that can diagnose diseases in cattle, and this system needs to be modernized.

Even if there is enough literature on the prevalence, causes, developmental features, clinical signs, diagnosis, treatment and group prevention measures in cattle, it is on the basis of experimental data that the diagnosis, analysis, causes of diseases in cattle, developmental features, clinical signs, prognostic models to help diagnose and treat have not been developed. There is no system for diagnosing diseases and the degree of disease in cattle, as well as assistance to the veterinarian in making decisions and optimal diagnosis.

CONCLUSION

A program has been developed for constructing the Sugeno model for diagnosing diseases in cattle. A computational experiment was carried out on the basis of the created software product. The results of a computational experiment are an additional tool for a veterinarian when making a decision on the diagnosis of cattle diseases and saves time when making a diagnosis.

On the basis of the developed program, a Sugeno fuzzy logical model was built for diagnosing diseases in cattle. The analysis of the adequacy of the results obtained by the fuzzy Sugeno model was carried out. The analysis showed that the result obtained by the Sugeno model gives a diagnosis error of 1.2%.

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