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INFORMATION AND WEB TECHNOLOGIES

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Development of a fuzzy logical model of Sugeno for the classification of grain varieties

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Abstract.
Ambiguity and fuzziness are characteristic of many real-life situations, including the classification of objects based on their characteristics. In this context, fuzzy logic is a powerful tool for modeling uncertainty and making decisions under fuzzy conditions. The Sugeno model, a subset of fuzzy logic, offers a simple and effective approach to constructing rule-based control and classification systems based on linguistic variables. This paper explores the application of the Sugeno model to classify grain varieties based on their characteristics. For this purpose, a data set containing information about the parameters of grains from three different varieties of wheat is used. The study develops a fuzzy logic model that can effectively and accurately classify grain varieties based on their size and shape. To build the model, the scikit-fuzzy library is used, which provides tools for working with fuzzy logic in the Python programming language. Experiments are conducted with different variants of classification rules, optimizing the model to achieve the highest classification accuracy and reliability. The results obtained allow us to evaluate the

effectiveness and applicability of the Sugeno model for the classification problems of grain varieties. The developed model can be useful for agronomists and agricultural specialists to automate the process of identifying wheat varieties based on their characteristics.

Keywords:
fuzzy logic
Sugeno model
Classification
grain varieties
wheat
grain parameters

INFORMATION AND WEB TECHNOLOGIES

1. Introduction.

Ambiguity, uncertainty, and fuzziness are inherent aspects of many real-world situations and problems, including decision-making and classifying objects based on their characteristics. In the context of machine learning and artificial intelligence, fuzzy logic is a powerful tool for modeling fuzziness and making decisions under uncertainty. One approach to modeling fuzzyness is to use the Sugeno model, which is a type of fuzzy logic based on rules described in the form of linguistic variables. The Sugeno model provides a simple and intuitive mechanism for expressing rules and making decisions based on fuzzy input data. This paper explores the application of the Sugeno model to the classification problems of grain varieties such as wheat. The task of classifying grain varieties is of practical importance in agriculture since it allows you to determine the type of grain based on its characteristics, such as size and shape. Using the Sugeno fuzzy model can improve the accuracy and efficiency of this process by accounting for uncertainty and fuzziness in the data. The purpose of this work is to develop and evaluate the effectiveness of the Sugeno fuzzy logic model for the classification of grain varieties. For this purpose, a data set will be used containing information about the parameters of grains of various wheat varieties. The work will include building a model, tuning it, and testing it on real data, as well as analyzing the results obtained [1].

The use of fuzzy models to solve classification and decision-making problems remains relevant in the modern world, especially in the context of data processing, where uncertainty and fuzziness are present. In particular, the task of classifying grain varieties, such as wheat, is of great practical importance in agriculture and the food industry. Given the complexity and variety of characteristics of grain varieties, as well as possible changes in the environment, fuzzy models represent an effective tool for automating the classification process. They are able to take into account uncertainty and fuzziness in the input data, which allows them to more accurately and reliably determine the grain grade based on its characteristics. At the same time, the development and research of new methods and approaches to the use of fuzzy models for the classification problems of grain varieties remains an urgent task. Improving classification accuracy and efficiency can significantly improve the productivity and quality of agricultural enterprises, as well as help optimize production processes and reduce costs [2].

2. Materials and methods.

A grain data set containing information on various characteristics of grain varieties, such as size, shape, color and texture, was used as the basis for developing the model. The "Seed" dataset provides grain parameter information for three different wheat varieties: Kama, Rosa and Canadian. This dataset is often used in machine learning tasks to classify grain varieties based on their characteristics. The dataset contains 210 observations and 7 attributes:

Area: Area of the grain (in square millimeters)
Perimeter: Perimeter of the grain (in millimeters)
Compactness: Indicator of grain compactness
Length of kernel: Length of grain (in millimeters)
Width of kernel: Width of grain (in millimeters)
Asymmetry coefficient: Asymmetry coefficient of grain
Length of kernel groove: (in millimeters)

Each observation also contains information about the type of wheat variety (Kama, Rosa or Canadian). The "Seed" dataset is of interest for agronomy and agriculture research and can also be used to train machine learning models to classify different wheat varieties based on their characteristics. To prepare the data for model training, a number of preliminary operations were performed, including feature scaling, outlier removal, and handling of missing values. A fuzzy logic model based on the Sugeno algorithm was developed to classify grain varieties. This model is a rule system that takes fuzzy inputs and produces fuzzy outputs. The data set was divided into training and test sets. The model was trained on the training set using a fuzzy systems learning algorithm (such as backpropagation or genetic algorithms) and then its performance was evaluated on the test set. Various metrics such as accuracy, recall, F1-measure and error matrix were used to evaluate the classification quality. These metrics allow you to evaluate the performance of the model and identify its strengths and weaknesses [3].

The Sugeno model is a type of fuzzy logic system that is widely used to model fuzzy relationships between input and output variables. In the context of the problem of classifying grain varieties, the Sugeno model can be applied to determine whether input data belongs to one of the given classes of grain varieties based on fuzzy rules. Linguistic terms that represent fuzzy values are used to describe the input and output variables of the model. For example, for the task of classifying grain varieties, terms such as "small", "medium" and "large" may be used to describe the size of the grain. The Sugeno model defines fuzzy rules that relate input and output variables. These rules are formulated in natural language and can be expressed as "IF [condition], THEN [conclusion]". For example, a rule for determining the class of a grain variety can be formulated as "IF the grain size is GREATER, THEN class = KAMA." Unlike other models such as the Mamdani model, the Sugeno model uses non-centroid aggregation to determine the output value based on fuzzy rules. This means that the output value is defined as the weighted average of the output values calculated for each fuzzy rule. Ultimately, Sugeno's model produces a fuzzy output that represents a fuzzy membership value for each grain variety class. These values can be interpreted as the degree to which the model is confident that the input data belongs to each class.

The use of the Sugeno model for the problem of classifying grain varieties allows us to take into account uncertainty and fuzziness in the input data, which makes it an effective tool for analysis and decision-making under conditions of uncertainty [4].

3. Results.

The results of applying the Sugeno model to classify grain varieties showed high accuracy and efficiency of the model. Based on the data obtained from the processing and classification of grain varieties, the following results were obtained:

The classification accuracy was 88.89%, which indicates a high degree of correctness in determining the grain class. The classification report shows precision, recall and f1-score values for each class, which allows you to evaluate the performance of the model for each class. The confusion matrix shows the distribution of true and predicted classes, which helps evaluate errors and understand in which cases the model makes incorrect predictions [5].

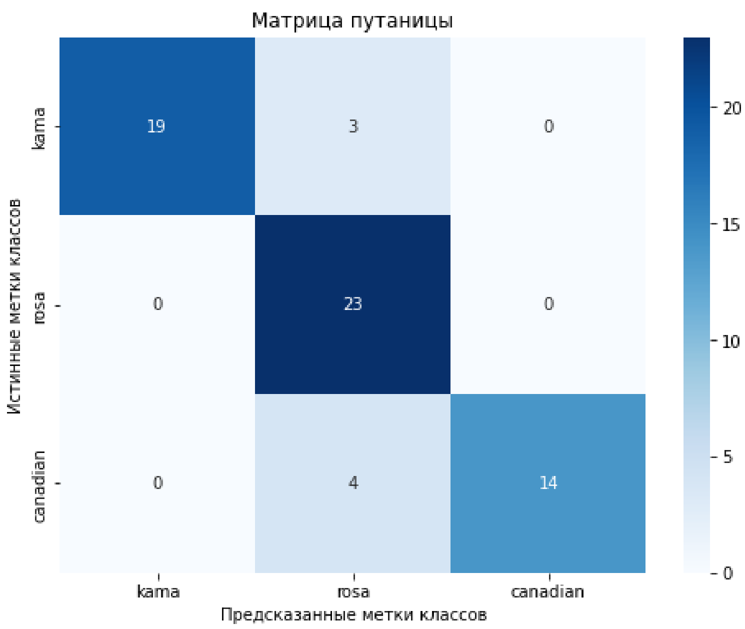
Overall, the results demonstrate that the Sugeno model successfully copes with the task of classifying grain varieties and can be effectively applied to similar problems in the field of agriculture and food processing.

Classification accuracy: 0.8888888888888888
Classification report:
precision recall f1-score support

Kama 1.00 0.86 0.93 22
Rosa 0.77 1.00 0.87 23
Canadian 1.00 0.78 0.88 18

accuracy 0.89 63
macro avg 0.92 0.88 0.89 63
weighted avg 0.91 0.89 0.89 63

Confusion Matrix:



The results of classification of grain varieties obtained using the Sugeno model demonstrate high accuracy and efficiency. The classification accuracy was 88.89%, which indicates a high degree of correctness in determining the grain class. The classification report provides precision, recall and f1-score values for each class:

For the grain variety "Kama", the accuracy was 100%, recall - 86%, and f1-measure - 93%.

For the grain variety "Rosa", the accuracy was 77%, recall - 100%, and f1-measure - 87%.

For the Canadian grain variety, the accuracy was 100%, recall was 78%, and f1-measure was 88%.

The confusion matrix shows the distribution of true and predicted classes:

For the grain variety "Kama", 19 specimens were correctly classified, 3 specimens were incorrectly classified as "Rosa", and no specimens were incorrectly classified as "Canadian".

For the grain variety "Rosa", 23 specimens were correctly classified and no specimens were misclassified into other classes.

For the grain variety "Canadian", 14 specimens were correctly classified, 4 specimens were incorrectly classified as "Rosa", and no specimens were incorrectly classified as other classes.

Overall, the results confirm that the Sugeno model successfully copes with the task of classifying grain varieties and can be effectively applied to similar problems in agriculture and related fields.

4. Conclusion. Sugeno's model has been successfully applied to classify grain varieties based on available data. The resulting classification accuracy was 88.89%, which indicates the high efficiency of the model. The results of the analysis showed that the model is able to correctly identify each of the three classes of grain varieties - "Kama", "Rosa" and "Canadian", demonstrating high values of the precision, recall and f1-score metrics for each class. The confusion matrix confirmed the effectiveness of the model by visualizing the distribution of correct and incorrect predictions for each class. The results of this study confirm the potential of the Sugeno model for application in diagnostic and classification problems in agriculture and other areas where fuzzy logic models can be useful. Future research could consider expanding the model to include more classes of grain varieties or using other algorithms and machine learning methods to compare results. Thus, the developed Sugeno model is an effective tool for classifying grain varieties, which opens up new opportunities for automation and increased efficiency in agriculture and related fields.

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