Logical-Linguistic and Logical-Probabilistic Methods of Image Classification in Decision-Making

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***Abstract* — The formation of images in the environment of choice and their classification is one of the important features that characterize the intelligence of modern robots. To do this, we are looking for logical patterns that can explain the available facts and predict the images being formed. Existing neural network methods require the use of pre-training on some training sample. Therefore, objects that are not included in the training sample cannot be classified. Also, the presence of contradictory examples in the training sample and a large noise level in the classified image has a significant impact on the decrease in classification accuracy. *Purpose*: Construction of new methods for searching for a set of logical connections inherent in the image, construction of classification models and development of structural and linguistic methods of classification of analyzed images. *Methods*: Logical-linguistic and logical-probabilistic classification methods are proposed, in which the decisive rule of classification is based on calculating the minimum sum of the squares of the differences in the values of the membership functions or probabilities of the elements of the attribute strings of reference and classified images. At the same time, to increase the accuracy of classification, the specified values of membership functions or probabilities can be multiplied by the coefficients of the significance of attributes. *Result*: The proposed classification algorithms were tested using computer simulation of classification using examples of image recognition in unmanned aerial vehicles, accident risk assessments when driving unmanned vehicles and risk assessments of project financing. The results of computer modeling showed that at a noise level of about 35% - 40%, the accuracy of image classification lay in the range of 78% - 95%. *Practical significance*: the research results can be used in various intelligent systems to improve the accuracy and speed of image classification.**

Keywords— images, classification, logical-linguistic, logical-probabilistic methods, testing, computer modeling.

I. INTRODUCTION

Inductive formation of images in the environment of choice and their classification based on the analysis of sensory data is one of the important features characterizing the intelligence of modern robots equipped with the central nervous system (CNS) [1]. The solution of this problem is connected with the search for logical patterns based on the construction of rules that can explain the existing facts and predict new or missing ones inherent in the desired or formed image [2, 3]. Therefore, the most important goal of the central nervous system of the robot is to build a set of logical connections inherent in the image, i.e. the construction of a classification model [4]. When the classification model is built, based on the found patterns, the robot can refer the objects considered in the Central Nervous System to any class [5].

Improving the accuracy of object classification in the selection environment is especially important for correct decision-making in the situational control of mobile robots [6]. This largely not only determines the quality of situational control, but also, most importantly, allows preventing collisions leading to emergency situations [7].

II. STATEMENT OF THE PROBLEM OF IMAGE CLASSIFICATION

In the task of classifying images from images in the central nervous system of an intelligent robot, based on the analysis of sensory data about the environment of choice, a set of images G = {g1,g2,...,gn} and a set of reference images (objects) are first formed in the database O = {o1,o2,..., om}. Usually these sets are ordered sets, and the elements of these sets are logical variables (LV) taking the value 0 or 1 [8]. Each image gi and each reference image oj are characterized by sets of features (attributes). The number of attributes is fixed; attribute values can be numeric, logical and symbolic. The presence of one or another attribute in the reference and the classified image is determined by the vision system or the CNS sensor system SEMS.

Various decision rules are used to assign images to a particular class of images. Usually [4] the decision rule selection Oq class of images is implemented by building the training sample Kq=Kq+∪Kq-, where Kq+⊂ Oq и Kq-⊂ Gq.. Based on such a Kq training sample, a comparison of positive and negative objects of the training sample is made. At the same time, the decisive rule is correct if it later successfully recognizes objects that were not originally included in the training sample.

A number of neural network algorithms are known that form decisive classification rules in the form of a decision tree, or a set of production rules. First of all, these are the IDT and C4.5 algorithms [3, 9], the CN2 algorithm [10] and a number of others. The neural network implementation of such algorithms requires the use of their preliminary training on some training sample. Naturally, with this approach, objects that are not included in the training sample will not be classified in the robot's selection environment.

One of the problems for the above-mentioned algorithms is the difficulties that arise when processing incomplete and contradictory information that was not or could not be taken into account when forming a training sample [11]. The latter, accordingly, leads to significant classification errors. In particular, the paper [4] investigated the effect of noise in the initial data on the effectiveness of classification models obtained using generalization algorithms. The most complex variant of noise in database tables was considered, associated with the presence of contradictions in the training sample. It is shown that the most significant influence on the decrease in classification accuracy is the presence of contradictory examples in the training sample, on the basis of which the decision tree is built, that is, examples attributed to different classes, with a complete coincidence of informative attributes.

In the same place [4] it was shown that with a noise level of up to 25% and with various training samples, the classification accuracy according to the IDT algorithm ranged from 78% to 85%, and according to the C4.5 algorithm – from 75% to 80%. At a higher noise level, such algorithms become ineffective.

III. Algorithms of logical-linguistic and logical-probabilistic classification

To overcome these limitations, so-called structural-linguistic recognition methods are being developed [3]. For example, in [5] logical-probabilistic algorithms for solving the classification problem are proposed, which allow achieving high classification speed with classification accuracy of about 80% and noise level up to (30-50)%.

Among the algorithms of logical-linguistic classification (LLC), the following can be used [12, 13].

LLC1, in which the decisive classification rule is based on calculating the minimum sum of the squares of the differences in the values of the membership functions of the elements of the attribute strings of the standards and the classified images. Such an algorithm, compared to known neural networks, makes it possible to simplify calculations while maintaining the accuracy and speed of classification.

LLC2, which differs from the LLC1 algorithm in that in it the decisive classification rule is based on calculating the minimum sum of the squares of the differences in the values of the membership functions multiplied by the significance coefficients of the elements of the attribute strings of the standards and the classified images. This algorithm can increase the accuracy of classification compared to the LLC1 algorithm and reduce the spread in accuracy depending on the type of image being classified.

LLC3, which differs from the LLC1 algorithm in that it classifies in stages according to individual groups of standards, and not according to their entire totality. This algorithm can increase the accuracy of classification compared to the LLC2 algorithm and reduce the spread in accuracy depending on the type of image being classified. However, the classification time may increase in some cases.

LLC4, which differs from the LLC3 algorithm in that it, classifies taking into account the coefficients of significance of groups of standards. This algorithm can increase the accuracy of classification compared to the LLC3 algorithm and reduce the spread in accuracy depending on the type of image being classified. However, the classification time may increase slightly in some cases.

The algorithms of logical-probabilistic classification (LPC) are similar to the previous ones, but instead of the values of membership functions, probability values are used [12 - 14].

Determining the values of probabilities requires considerable time for the accumulation and processing of statistical data. However, with the long-term operation of intelligent robots, such algorithms can be recommended to improve the accuracy of classification.

IV. Examples of testing algorithms

Testing of the described algorithms and software tools was carried out using computer modeling of image classification using examples of image recognition in unmanned aerial vehicles (UAVs), accident risk assessments during the movement of unmanned vehicles (UV) and risk assessments of project financing.

A. Pattern recognition in the field of view of the UAV

During testing, the following groups of objects were considered [14]: s_1 - ground equipment; s_2 - watercraft; s_3 - aircraft; s_4 - people. At the same time, all images of objects were characterized by a set of types of attributes and the values of their membership functions assigned by a group of experts. Each of the object images was tested 100 times.

Attribute values and their significance coefficients were set by experts. For example, the classification of car images was carried out according to the following types: Jeep X1j, crossover X_{1c}, sedan X_{1s}, hatchback X_{1h}, pickup X_{1p}. The following reference lines were used for car types: 1- presence of an attribute, 0 - absence:

- - for jeep {0 1 0 0 1 0 0 0 1 0 1 0 0 0 1 0},
- - for crossover {1 0 0 1 0 0 0 1 0 0 1 0 0 0 1 0},
- - for sedan {1 0 0 1 0 0 1 0 0 1 0 0 0 1 0 0},
- - for hatchback {1 0 0 1 0 0 1 0 0 0 0 1 0 1 0 0},
- - for pickup {0 0 1 0 0 1 0 1 0 0 0 0 1 0 0 1}.

The results of computer modeling have shown the high efficiency of the proposed classification methods. For example, even the simplest algorithm of LLC1 (Fig. 1) showed that with a noise level of about 35% - 40%, the accuracy of the classification of software lay in the range from 78% - 95%.

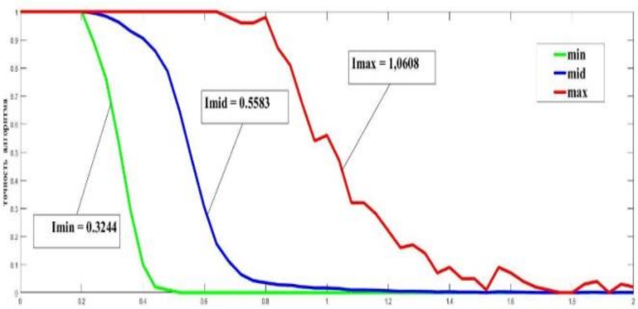

Fig. 1. Simulation results of LLC 1

B. Risk assessments of accidents when driving UV

Poorly predictable variability of the UV functioning environment and imperfection of measuring instruments reduces the possibility of obtaining comprehensive information about the state of the environment, which leads to a situation where a decision on the route with minimal travel time and the probability of an accident is made in conditions of incomplete certainty. One of the effective ways to solve this problem is the use of logical-probabilistic and logical-linguistic models and algorithms. At the same time, rows of parameters and characteristics of reference traffic sections are created. They are compared with the lines of logical-probabilistic and logical-linguistic parameters of the classified sections of traffic routes, taking into account their significance when making a decision. These lines are obtained after processing sensory and statistical data about the selection environment.

The formation of the functional based on the proposed classification and its minimization, as shown by the results of computer modeling, makes it possible to increase the accuracy and speed of choosing the optimal route of the UV [15].

C. *Risk assessments of project financing.*

To determine the project proposed for financing, the concept of Project financing was used as one of the classes of specialized lending in accordance with the Regulations of the Central Bank of the Russian Federation. When computer modeling of the proposed method was carried out: assignment of weight coefficients for all subclasses of credit requirements specified in the Regulation; assignment of risk degrees for all values of criteria types, introduction of tables of risk assessment values or the level of creditworthiness of the project, formation of a database of reference attribute strings for all classes of projects, formation of attribute strings of the analyzed project, attribution of the analyzed project to one of the reference ones using the method of logical-linguistic classification, assignment for the analyzed project values of risk degrees for all values of criteria types (attributes) of the selected reference project, calculation of the credit risk assessment of the analyzed project and determination of the rating of the analyzed project for decision-making [16].

The test results showed high speed and stability of estimates by the proposed method.

V. Conclusion

When creating the central nervous system of an intelligent robot, it is necessary to build classification models of objects in the selection environment. The accuracy of classification of existing neural network methods decreases with a significant level of interference in the classified image. This leads to the need for additional training of neural networks. Therefore, classification algorithms using neural networks, unlike the proposed algorithms of logical-linguistic and logical-probabilistic classification, with a noise level above 80%, as a rule, become ineffective and require additional training time.

The proposed logical-linguistic and logical-probabilistic methods of image classification are implemented in the form of computer programs that speed up the recognition process and increase accuracy with a significant level of interference. At the same time, to assess the effectiveness and stability of the algorithms, simulation computer modeling was used, generating hundreds of possible combinations of attributes and values of their membership functions, taking into account their probabilistic distribution.

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